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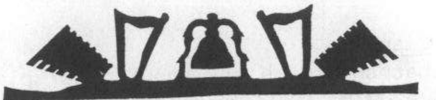
FOR THE DESIGN, CONSTRUCTION AND ENJOYMENT OF UNUSUAL SOUND SOURCES

EXPERIMENTAL MUSICAL INSTRUMENTS



IN THIS ISSUE

CABBAGES AND KINGS

Inside this issue you will find a report by Tom Guralnik on the "(not so) Mobile Saxophone and Mute Unit," a battery of saxophones, near-saxophones, and preparations thereto, through which he has evolved a distinctive solo performance style. Also within is an essay from Douglas Kahn on imaginative instruments that have appeared in fictional literature, more on musical string design calculations from Cris Forster, some book reviews from Charles Adams, and several more odds and ends.

Starting here on this page is a discussion and general overview of percussion aerophones -- instruments whose primary tone comes from a tuned air column or chamber excited by percussion. This article is a companion piece to a report on New Zealand's From Scratch ensemble, whose members have developed an impressive array of percussion aerophones for their grand-scale performances. The From Scratch article will appear in EMI's coming December issue. Meanwhile, here is our introduction to percussion aerophonics.

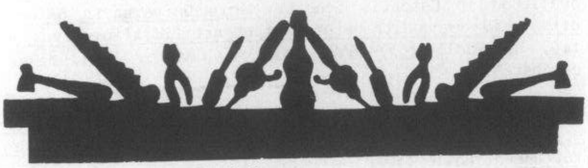
PERCUSSION AEROPHONES

By Bart Hopkin

Percussion aerophones are musical instruments in which a body of air is excited by some sort of sudden jolt. The jolt is generally the result of something hitting something. For a simple and familiar example, consider an open jar with a reasonably large mouth. If you strike the rim with a short, sharp rap of your open hand, you will hear a brief but agreeable tone at the resonant frequency of the enclosed air. The resonance is excited by the abrupt pressure surge caused by your hand, and perhaps also by the glass's movement at the moment of contact. (The glass itself has its own timbre and frequencies, unmistakably different from the air resonance. It is comparatively quiet when you strike with your hand. But, by way of instructive contrast, if you were to strike the jar with a small metal beater instead, that glass sound would predominate. You'd then have to say that the same instrument, now sounded differently, acts primarily as an idiophone.)

As the above example suggests, percussion aerophones usually involve some kind of enclosed air chamber. The most common and practical form

(continued on page 12)



Graphics this page by Robin Goodfellow

LETTERS

A GOOD FRIEND OF MINE, Pascal Payen Appenzeller, a well-known historian, gave me a photocopy of a book Les medecines de la Folie (Curing insanity) written by Dr. Pierre Morel and Claude Quetel; Pluriel-Hachette Pub.

I translate:

Cat Piano

What should we say about a cat piano? The idea that such an instrument could have existed gives a lot to think about, even if it was built on an experimental basis: A piano where strings are replaced by cats, each of them giving a different note.

It seems that Father Kircher, a German Jesuit of the XVIIth century with an interest in musical things, gave the first description of this weird and cruel instrument.

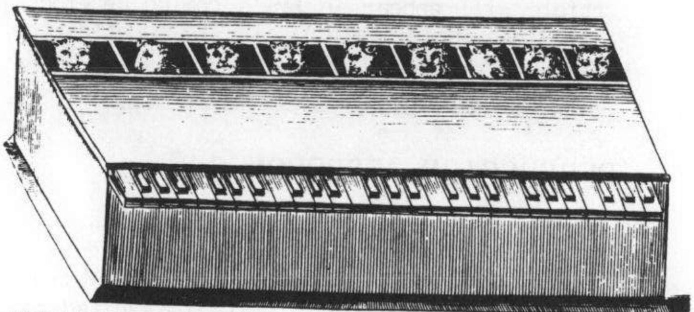
"Not long ago," says he, "an actor, as ingenious as illustrious, built such an instrument to cure the melancholy of a great Prince. He gathered cats differing in size and therefore in the pitch of their voices. He enclosed them in a basket specially built for this purpose, so their tails, coming out through holes, were held in tubes. He added keys with thin needles instead of hammers, and installed the cats according to their voices in such a way that each key would correspond to the tail or an animal, he and put the instrument in a suitable place for the pleasure of the Prince. Then he played it, producing chords corresponding to the mewings of the animals. Indeed the keys pressed by the fingers of the musician, by torturing the tails of the cats, would enrage the poor animals and would make them scream with a high or low pitch, producing a melody that would make people laugh or even incite mice to dance."

It is possible to doubt the reality of such a machine if we consider an engraving of the same period, drawn by François Van den Wingaerde of Antwerpen, that shows a funny concert for piano and choir of grotesque animals. This engraving could very well illustrate what Germans call "Katzenmusik," which means total cacophonia.

Nevertheless, Johann-Christian Reil, renowned neuro-anatomist from Germany, mentions the Cat piano (Katzenklavier) in a list of therapies for mental illness, published in 1802. He even specified that the patient has to sit "in such a way that he does not loose sight of the physiognomy and the mimicry of the animals. ... Even even more upsetting is the voice of the animal with long ears (the donkey) but unhappily, in spite of his little talent he has caprices like an artist."

This would induce us to think that this is rather a joke, if we did not know on the other hand to what extent, in his book, Reil has given a great importance to all the means based on pleasure and pain. From skin tickling to opera music, including firearm detonations and sexual intercourse, everything works as long as you can induce a salutary emotion in the mad person. So why not the cat piano?"

Francois Baschet



PIANO A CHATS
(C. Schott. "Magia universalis" Bibl. municipale de Troyes).

The Cat Piano engraving is by Francois Van den Wingaerde, published in Casparis Schott: Magia Universalis naturae et artis, sive recondita naturalium et artificialium rerum scientia. Herbipoli 1657-1659. Vol. 4, Chapter "Felium musicam exhibere".

Johann-Christian Reil quotes are from Reil, J.C.: Rhapsodieen uber die Anwendung der Psychischen Curmethode auf Geisteszerruttungen, Halle 1803.

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SUBMISSIONS: We welcome submissions of articles relating to new or unusual musical instruments. A query letter or phone call is suggested before sending articles. Include a return envelope with submissions.

I VERY MUCH ENJOYED discovering Buzz Kimball's musical world and thought as described in his article "Toward a Music of the Hyperspheres" (EMI, June, 1990); I write only to take issue somewhat with his assessment of Harry Partch (p. 9). It is certainly true, as Mr. Kimball implies, that Partch developed a very specific kind of just intonation; there are other ways to construct a system of "rational" tuning, depending on one's preferences for mathematical, technological, harmonic or melodic criteria in developing such a system. However, the "bizarre cult" which Mr. Kimball sees Partch as "spawning" is quite diverse in nature; while some have more or less taken over Partch's system, others have followed his dictum of "doing your own thing" and have evolved many different kinds of systems. I would look elsewhere for disciple-infested cults.

It is also true that early (i.e. pre-1950) recordings of Partch's music have been nearly impossible to come by in recent years (although the CRI items still available date from the 1950s). However, my experience in introducing people to Parch has been the opposite of Mr. Kimball's. Those hearing the later CBS recordings (World of Harry Partch and Delusion of the Fury, both sadly out of print) for the first time usually fall in love, while the old recordings of the Li Po songs and the Intrusions (that I and Mr. Kimball, I presume, like) tend to inspire bemusement more than attachment among the uninitiated. Perhaps higher fidelity's responsible, or Partch's emphasis on percussion in his later music. Whatever the reason, there it is.

Richard Kassel

A FEW MONTHS AGO i (finally) managed to get to the Ontario Science Centre in Toronto. While much of the center is devoted to natural sciences, space exploration and food-related stuff, there is also a remarkable set of displays (all very hands on) on music. One of the first things the visitor sees (and hears) is the display of gamelan instruments. While most visitors didn't have a very musical approach to it (i.e. "let's bang this thing as hard as we can and hear the funny sounds") i was having a great time trying to work out a few melodies on the various instruments. There were other percussive instruments there, such as a conventional drum kit (safely enclosed in a soundproof booth), as well as a rather strange-looking instrument, a type which i've seen depicted in EMI in the past. I'm not sure who was the maker (i wasn't exactly prepared to take notes), but I think it was Francois Baschet. This was a really lovely instrument to play (with). I wish i had something in my "studio" where i could study its sonorities in a serious manner. There were also various MIDI instruments set up, meant to demonstrate various aspects of MIDI technology. Unfortunately, much of the controls on these instruments were disabled, aside from the ones the exhibit makers wanted you to tweak. There was also a display of organ pipes, but it was out of commission then. Lastly, in the "steam-age technology" section, i found a reproducing player piano. The roll that they had on the instrument was pretty mundane, unfortunately (no Nancarrow rolls, sorry).

Here's a challenge for EMI and its readers: It has been widely documented that Conlon Nancarrow's pianos have been modified, but the specific nature of the modifications have not been documented, to my knowledge. Let's see someone get to the heart of the matter and figure out what makes these instruments tick. Surely Nancarrow isn't keeping this a secret. If there were several more of the specially modified pianos out there, it would be a lot easier to organize live performances of his music. It would also make it a lot easier for other composers with similar inclinations to compose for the instrument.

Colin Hinz

IT WAS WITH GREAT ENTHUSIASM that I received the August edition of EMI for it contained the excellent article by Ed Stander on the Musical Glasses. Since I have a similar interest and have done a bit of research on the same topic, I have several comments that could add to the data presented for your readers.

There are numerous references extant to the musical glasses prior to Richard Puckridge. Considering only the European lineage that started at least as early as 1492, there is, for instance, the 1596 Viennese museum catalog that describes an "instrument von glassmerck" that played a range of three-and-a-third octaves including semitones. There was also George Philipp Harsdorfer's "Mathematical and Philosophical Hours of Relaxation," printed in 1677 at Nuremburg (Part 2, Pg. 147). "To produce a merry wine-music, take eight glasses of equal form; put in the one a spoonful of wine, in the other two, in the third three, and so on; then let eight persons, with fingers dipped in wine, at the same moment, pass them over the brim of the glasses, and there will be heard a very merry wine-music, that the very ears will tingle; but you can arrange it also with fewer glasses, by order of intervals of thirds, fifths, and octave; and according to the size of the glasses, augment or diminish the wine." Musical Glasses were also mentioned in "Manual of Inventions" by C.E. Benj. Busch in Eisenach, 1812.

I have always enjoyed the curious account by the seventeenth-century Jesuit priest, Althanasius Kircher, who put forward the theory that the listener's mood could be variously influenced by filling the glasses with different liquids, such as brandy, wine, distilled water, seawater or pumpwater. The diverse sounds were thought "even to have the power of alleviating or curing such disorders as thickness of the blood."

As to the names assigned to the glass instruments, this is a point of considerable current controversy. There seems to be general agreement these days to call sets of individual glasses "The

Musical Glasses," and the mechanized version invented by Benjamin Franklin "The Armonica" (note use of Franklin's own spelling as included in his 1762 letter to his friend, the Italian prelate and scientist Beccaria: "In honor of your musical language, I have borrowed from it the name of this instrument, calling it the Armonica"). In this way there is hope to counteract the historical tendency to lump all rim-rubbed glass instruments under the umbrella term "Harmonica."

As for "Angelica" being the original name for the Musical Glasses, that leaves out such intriguing candidates as Verillon, Angelic Organ, and my personal favorite from England, the Seraphim. Perhaps we can also hope to establish the credentials of the polysyllabic "Hydrodaktulopsychicharmonica" sometime as well!

Regarding the tuning methods on the old glasses -- it is perhaps true that some were fortuitously blown to just the right pitch. One should consider too, however, the common practice of grinding the rims and, in some cases, the bowls during the finishing process to raise or lower the pitch as required.

Looking to the reference to Wolfgang Amadeus Mozart -- he died in 1791 and did not posthumously compose the "Adagio & Rondo in C", K.617 in 1792. The official date of the composition's completion is May 23, 1791, less than seven months before Mozart's death. By the way, the premier public performance was scheduled for June 13, 1791, but did not actually take place until August 19 of the same year.

When considering Bruno Hoffmann's unparalleled contribution to the preservation and advancement of the Musical Glasses, one must keep in mind that even he was unable to play the Armonica works without significant alterations to the original scores. Of course, these were necessitated by the remaining limitations, however minor, inherent in his clever individual glass layout. The subtlety and artistry Herr Hoffmann brought to bear in arranging these works and performing them throughout his long and illustrious career serve as a major inspiration to anyone who attempts to revive the original Armonica instrument and its repertoire.

In closing, I thought I would send along a photocopy of what appears to be an original score for the "cat piano." It is now used as a logo for the Italian musical organization Cidim Comitato Nazionale Italiano Musica. I'm not quite clear on how the positions of the cats relate to the lines to give the pitch indications, so perhaps some of your readers can explain.

Dennis James

For a listing of upcoming glass music performances by Dennis James, as well as his cassettes & CDs of Armonica music, write him at 1563 Solano Ave., Suite 281, Berkeley CA 94707.

Above: Cat music logo for the Italian musical organization Cidim Comitato Nazionale Italiano Musica.

I AM WRITING in response to Ed Stander's article entitled "Notes on the Musical Glasses" [EMI Volume VI #2]. Mr. Stander wrote, "The note produced by a given glass depends on the mass of the glass ..." He concludes that water in a glass "... increases the effective mass of the bowl, and therefore decreases its pitch." This conclusion is essentially correct. However, there is another equally important variable besides mass (m) which also influences the frequency (F) of glasses. It is called the stiffness (K) of the glass. The effect of this variable can yield surprising results. By removing material from the rim of a brandy snifter (cone shaped) glass, decreasing the mass results in decreasing the frequency of the glass as well! This principle is also at work while tuning marimba bars: by cutting an arch underneath a bar, both the mass and the frequency are decreased simultaneously. These results are achieved by decreasing the stiffness of the respective materials.

The simplest mechanical model which demonstrates the behavior of vibrating glasses and bars is a spring. A spring can be made to oscillate by attaching a weight to one of the ends. The frequency by which the weight moves up and down is determined by the mass of the weight and by the stiffness of the spring material. A general equation governing the frequency of oscillation for a spring states:

$$\sqrt{\frac{K}{m}} = F \quad \text{or} \quad \frac{K}{m} = F^2 \quad \text{(per 2 * Pi seconds).}$$

The ratio K/m demonstrates that K is directly proportional to F^2, or

$$K \propto F^2.$$

If K is doubled then F^2 is doubled, as in

$$(K * 2) = (F^2 * 2).$$

This ratio also demonstrates that m is inversely proportional to F^2, or

$$m \frac{1}{\propto} F^2$$

If m is doubled then F^2 is halved, as in

$$(m * 2 = F^2/2).$$

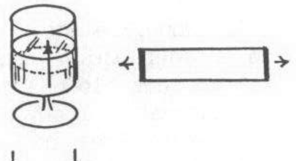
In the chart [on the facing page] eight different permutations of stiffness and mass with respect to frequency are discussed in detail. An arrow pointing up indicates an increase of K, m, or F^2. Similarly, an arrow pointing down indicates a decrease of K, m, or F^2. A 0 indicates no change.

Situations 1-4 illustrate the individual and separate effects of K and m on F^2, as when one of the two variables remains unchanged. Situations 5-8 illustrate the combined effects of K and m on F^2. Except in cases 3 and 4, drawings of glasses and bars demonstrate how these objects can be

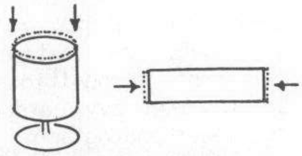
VARIABLES K or M UNCHANGED

$m \frac{1}{\propto} F^2$

1. $\frac{K^{\circ}}{m\uparrow} = F^2\downarrow$ F^2 decreases by adding water to the glass (which contributes no stiffness to the glass); or by adding very small amounts of wood to the ends of the bar without changing the stiffness of the bar.



2. $\frac{K^{\circ}}{m\downarrow} = F^2\uparrow$ F^2 increases by removing very small amounts of glass or wood without changing the stiffness of either glass or bar.



$K \propto F^2$

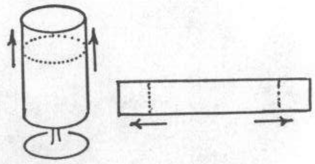
3. $\frac{K\uparrow}{m^{\circ}} = F^2\uparrow$ F^2 increases without changing the mass of either glass or bar by <u>freezing</u> them.

4. $\frac{K\downarrow}{m^{\circ}} = F^2\downarrow$ F^2 decreases without changing the mass of either glass or bar by <u>heating</u> them.

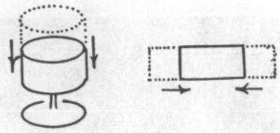
VARIABLES K & M CHANGED

$\left[\begin{array}{l} K \propto F^2 \\ m \frac{1}{\propto} F^2 \end{array}\right]$

5. $\frac{K\downarrow}{m\uparrow} = F^2\downarrow$ F^2 decreases by making either glass or bar substantially longer.

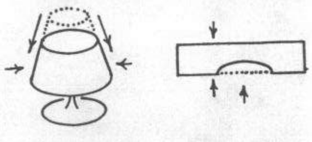


6. $\frac{K\uparrow}{m\downarrow} = F^2\uparrow$ F^2 increases by making either glass or bar substantially shorter.

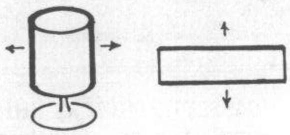


$K \propto m \propto F^2$

7. $\frac{K\downarrow}{m\downarrow} = F^2\downarrow$ F^2 decreases by removing material from the rim of a cone shaped glass and from the center of a bar, or by making the entire glass or bar thinner.



8. $\frac{K\uparrow}{m\uparrow} = F^2\uparrow$ F^2 increases by making either glass or bar thicker.



physically manipulated to conform with the changes of either K or m.

Cone shaped glasses are a unique example demonstrating the effect of K. By removing material at the rim of this glass, the diameter gets larger, and the walls of the glass decrease in stiffness. The frequency continues to decrease until a threshold is reached, approximately 1/2 inch down from the original top. From this point on, the stiffness of the walls can only increase, causing a corresponding increase in frequency.

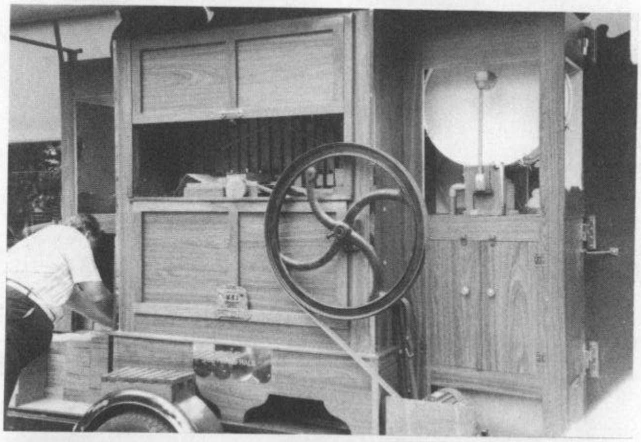
It should be noted that water is not a spring: it has no stiffness. Its only contribution to a vibrating glass is mass.

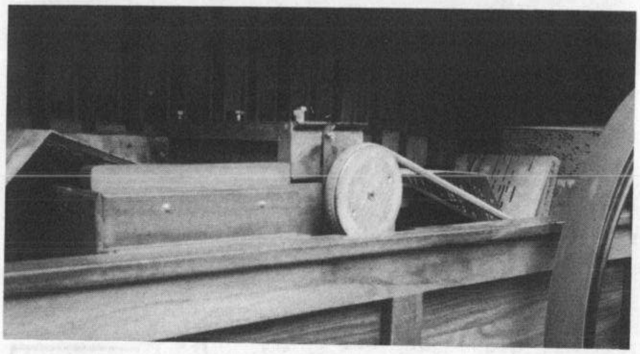
For further reading on the general behavior of springs, I recommend <u>Mathematics and the Physical World</u>, by Morris Kline.

Cris Forster

NOTES FROM RECENT CORRESPONDENCE

Tom Nunn, recently returned to the U.S. following a tour which took him to several European cities, sent along some photographs of a mechanical street organ in Amsterdam. The whole instrument rides on a large trailer; notice the organ pipes within and the large drum and beater at right. The instrument is programmed to play different compositions by means of perforated sheets of heavy cardboard, partially visible in the lower photograph.





NO CASSETTE REVIEWS THIS TIME: In each of the last several issues, EMI has included short reviews of independently-produced cassettes featuring new and unusual instruments. They've been bumped from this issue due to our chronic space problems, but there will be more in future issues.

CORRECTIONS

We have received word of two address corrections:

The address for ordering the tape Picture Noises from the Global Swamp, reviewed in EMI Vol. VI #1, has changed; it's now c/o Colin Hinz, ASFi World Headquarters, 208 Laclie St., Orillia, Ontario, Canada, L3V 4NG.

In EMI's review of just intonation software programs (Vol. V #6) an incorrect zip code was given in the address for the Microtonal MIDI Terminal software. The correct address is Denny's Sound and Light, PO Box 12231, Sarasota, FL 34278.

THE EVOLUTION OF AN INSTRUMENT: A WORK IN PROCESS / A CATALYST FOR MUSICAL DEVELOPMENT

By Tom Guralnik

Ever since beginning to play the saxophone some 20 years ago, I have been interested in working in, on and around that instrument to explore a world of sound not normally associated with it. More specifically, I have been interested in developing a vocabulary of personal and idiosyncratic sounds. For many years, I worked toward this through extended techniques, imitation of other instruments and so on, periodically seizing upon sounds and incorporating them into a growing personal language. But it really was not until 1979, when I had reached a certain musical maturity and technical prowess, that my own approach to extended saxophone playing began to take shape in my mind and in practice. It was at this point, when I began playing solo saxophone concerts, that I began to think not only about extending techniques of my saxophone playing, but about actually extending and altering the instrument I was playing. Since that time, my instrument has been in a virtually constant state of evolution, in which each physical change of the instrument has triggered aural and visual changes in the music/performance. In this article, I will attempt to describe not only the physical changes I have made but also how I have arrived at them and how they have affected the music.

I came to the decision to change the instrument for a number of reasons. One's decisions are always made as a result of an interplay of choice, chance, personal background, personal limitations, personal strengths, etc. This decision of mine was no different. In the first place, I saw limitations in the approach that required delving deeper and deeper into the technique of the saxophone to find a new language. On a philosophical/aesthetic level, I saw much of this extended technical territory already being charted and codified by the likes of Coltrane, Braxton, Evan Parker and others. And I wondered just what it was that I could add to this exploration. More personally, I didn't think that this area of technical exploration had ever been or would ever be my personal strength.

Secondly, I took inspiration from the example of others to move into the realm of instrument modification. Multi-instrumentalism (Braxton, Roscoe Mitchell) suggested ways in which a single musician could explore instrumental texturalization and colorization within the context of a performance. Percussionists had taken this approach one step further by developing their own personal set-ups, comprised of found, invented/altered, and chosen instruments arranged on racks for accessibility.

The "(not so) Mobile Saxophone and Mute Unit." Author Tom Guralnik takes advantage of the two sax stands to play two at once (as described on page eight).

Photographs for this article by Susan Ricker

Thirdly, while I didn't think that strictly saxophonistic technical prowess would be my forte, the process of building and construction, and the materials used in these processes, had interested me for years. I was an apprentice silver-flute maker at the Verne Q. Powell Flute shop for two years, and a repairperson of handmade silver flutes for several years after that. Additionally, I have always worked at and enjoyed construction and maintenance activities such as plumbing and carpentry. To integrate these extra-musical skills and interests into my music making activity is not surprising and actually very satisfying to me.

Thus, after some eleven years of solo performing, I have developed the instrument into a conglomeration of individual components: tenor and soprano saxophones, vacuuphones, invented woodwinds and electronics, all equipped with a changing array of mutes and sound altering devices and mounted on and within a 10 foot square sculptural structure. This structure allows me to move quickly and freely from one sound to the next. Just as my performance method has been largely improvisational, so too has my method of instrumental development. When I began altering the saxophone in 1979, I had no idea that it would end up as it has today. And similarly, I have no delusions that this is the instrument I will play for the rest of my career. What we have then at present is a snapshot in the development of the instrument. And what I will attempt to explain is some of the process of development that has taken place.

I began in 1979 by doing a series of four Sunday afternoon solo concerts. It became my goal to develop a new saxophone preparation (as in prepared piano), or to invent a new instrument, each week. In the concerts, in addition to playing the tenor saxophone, I would do short instrument studies for each new instrumental development. The first of these was the use of a trombone harmon mute in the bell of the tenor (padded with foam rubber to make it fit). I explored this new color (which only affected the very bottom of the horn) and then, through the use of various techniques, I attempted to wring every last bit of music I could from this preparation. I used embouchure methods to achieve slides of various kinds, and opened certain tone holes above the low notes to color the basic sound I was getting from the mute, creating new sounds to add to my vocabulary. I would look around my flute repair shop or around the hardware store for other instrumental preparation inspirations. One such preparation came in the form of the buffing wheels which I used to polish the flutes. I affixed one to the bell of the tenor, using gaffer's tape (the musician's best friend), replaced later by velcro (my best friend). As I played I would shake the tenor to open and close the bell with the buffing wheel and create a Wah Wah effect ... in my mind, a kind of saxophonistic version of Duke Ellington's trumpet wah wah jungle sound. This became another instrument study.

It was around this time that swung corrugated tubes (described as "whirlies" in a previous issue of this magazine) had become popular as a children's toy, and were appearing in some percussionists' set-ups as well. So the next week, looking around my repair shop and seeing the shop-vac sitting there, I started to explore the sound of swinging/singing corrugated vacuum tubes. Once again, my interest was in sounds which were unique

and personal, and I therefore took the instrument one step further than its whirly configuration by attaching a saxophone mouthpiece to it and calling it a vacuuphone. By using various embouchure techniques combined with closing and opening the end of the tube, as well as swinging it over my head periodically, I found that I could achieve a surprisingly varied and beautiful sound from the instrument, and so, I added it to my arsenal. Not long after this, I got my soprano saxophone out of mothballs and began to prepare it in various ways as well.

In addition to using pre-existing trombone and trumpet harmon mutes, buffing wheel mutes, and the vacuuphone, I also began to construct my own preparations to the saxophone. By using a piece of PVC shaped to be lodged in the full length of the soprano, I found that I could create multiphonics on a variety of tones simply with normal fingerings. I also placed pieces of tin-foil around the saxophones (later, tin foil attached to embroidery hoops held onto the saxophone bells by velcro) to achieve an effect whereby certain notes more than others would give rise to sympathetic vibrations of the tin foil, much like bottle cap buzzers on an mbira or kora.

In addition, I began to use other instruments in conjunction with my saxophone. While playing the saxophone with one hand I would swing various things with my other. I used corrugated tubes without mouthpieces, or elastic band-bull roarer-type instruments (commercially made toys called Hummingbirds or larger handmade instruments by Darrell Devore called D-trads). Or else I began to use a few hunting calls of the kind with a built-in reed activated by a rubber bellow -- deer calls or turkey calls -- which could be shaken with one hand while I played the saxophone with the other. Similarly, with my feet I would play various bicycle horns, originally taped to the floor at each performance and later held permanently on wooden boards with rubber surgical tubing.

I went through a short period where I began to attach things to the saxophone itself. Knowing that this would begin to damage the saxophone, I felt that this would be an important hurdle to overcome ... to begin to personalize the instrument in such a way that it could only be played in my own personal style. The personalization would naturally destroy it for conventional playing. And while I still feel this may be a way to go in the future, I have never been able to really decide to leave the "saxophone as saxophone" behind me. With the first big scratch and dent incurred from screwing a ratchet to the bell of the horn, I largely abandoned this direction and attached the ratchet to the bicycle-horn-floorboard instead.

Around this time, I also traded in my bass clarinet and bought a baritone saxophone. I then was playing soprano, tenor and baritone saxophones. Looking at the stand for the bari made me realize that it might be possible to build a similar stand for the tenor and soprano saxophones so that I could be freed from holding them as I played other "little instruments" (as named by the Art Ensemble) or even as I played the two saxophones simultaneously.

TOP: Tenor sax with a trombone harmon mute.

CENTER: Solo Vacuuphone

BOTTOM: Tenor with tin foil

Thus, I designed and built stands for the instruments and they remained always at playing height. This was my first use of drum and microphone stands to begin holding instruments. I found now that I could finger and play the tenor and soprano simultaneously and be freed from supporting their weight (which can limit somewhat what one is able to do ... although Rasaahn Roland Kirk (obviously an inspiration for my thinking in this direction) overcame these limitations quite amazingly). Subsequently, I found that the stands let me to play the saxophones in different ways by allowing me to move my hands without supporting the instrument. This would allow me, particularly

TOP: Tin foil vacuuphones.

CENTER: Soprano blow pipe (one of the travelling sounds)

BOTTOM: Tenor with vac extension and ragg mute.

on the soprano, to play the keys almost as if they were a piano keyboard. Specific sounds stemming from this new manual freedom subsequently became a part of my vocabulary. They often were combined with my newly learned technique of circular breathing.

As I have indicated, I would play individual pieces on all of the separate components, creating pieces which I called Instrument Studies. But the idea of actually integrating the individual parts of the instruments into one instrument started to come to me as I became tired of the degree of compartmentalization of my sounds. So in 1981, as I recorded my first album, I built the first rack to hold all the preparations and the saxophones, and called it the "(not so) Mobile Saxophone and Mute Unit."

All along the way, as each new development came about, parts of the past would be edited and discarded. Therefore, when I built the MSMU, I discarded some of my less personal sounds -- sounds which I felt I could not mold enough to take on my character and lose their own built in character -- such as the bicycle horns, and some of the other small instruments. Similarly, I had begun to play more animal/game calls in performance. But after hearing what saxophonist John Zorn had developed simultaneously in this area, I stopped playing these instruments as well. Like the bicycle horns, they lacked flexibility; and, in addition, I felt that there was no way to escape (either in my mind or in the audience's mind) the comparison between my use of game calls and John's similar instrumentation. While I was not afraid of defending myself against charges of rip-off, the more important issue for me was that this referential material (even if unintentionally so) could only distract from a personal statement I was trying to make ... could only result in drawing the audience and myself out of the personal world I was trying to envelop us in.

The first incarnation of the MSMU was, in addition to the racks which held the saxophones at playing height, merely a collapsible rack with pegs which held the mutes conveniently in front of me within easy reach, to be picked up and dropped into the various horns. At this point, I developed a few new mutes (ragg mutes), edited out some old ones and began to play pieces which would utilize each saxophone prepared in a different way (tenor harmon mute/soprano, PVC/baritone ragg mute, for example) and I would move from sound to sound and instrument to instrument, juxtaposing these preparations against each other in a linear fashion. These then were multi-instrumental studies utilizing prepared saxophones. And they became what I called "Sound Settings." Concerts would include various sound-settings, various instrument studies, etc.

What should become clear then is that as each new development of the instrument took place, the music would change considerably. With each technical change of the construction, new possibilities revealed themselves. And these new sounds in turn suggested still further sonic possibilities.

Around this time (1980-81), I did my first multi-track recording (Albuquerque: Cleo 001) utilizing layering of many of my muted/mutated/ prepared saxophone sounds ("Mutants") as well as my invented instruments such as the vacuuphones ("Familiar Currents"). In addition to the original swung vacuuphone, I had recently placed corrugated tubes of varying lengths on a rack as drone-type vacuuphones used for very specific effects and sounds. One of these was the water vac, the shortest corrugated tube, which I played into a container of water, using a soprano mouthpiece. Then there were the tin foil vacs: two tubes to be played simultaneously toned half steps apart. And finally, I had the contra-bass vac, producing an almost sub-sonic tone created by a wider, approximately six-foot long, clear vinyl, non-

corrugated tube with a bass saxophone neck and baritone mouthpiece. All these were attached with worm-type hose clamps to a boom stand. On the piece, "Familiar Currents," they formed a vacuuphone choir for the solo sound of the original vacuuphone which I now called Solo-Vac. Overdubbing was an interesting technique, allowing me to do some new things, but it seemed feasible only in the studio situation ... for a while at least.

As I began to be bothered by certain limitations in the music, I began to think about reconstructions of the instrument to overcome these limitations. I began to look first of all for more mobility within the set-up to allow for quicker changes of sounds. I was concerned with what felt at the time to be an undue amount of space between sounds necessitated by the physical movement from one instrument to the other. In addition, as I travelled more, mobility of the unit was becoming more of a concern. And since I had replaced the baritone saxophone with a bass saxophone (thus making an all-Bb-saxophone choir), I found that I was increasingly unable to transport all the saxophones. And so, to deal with all these issues, I started rebuilding the Unit.

In order to move more freely between sounds, I devised a way to mount the mutes on racks so that I had the choice of either placing the mutes in the saxophone, as before, or removing the saxophone from the stand and placing it onto the various mutes and preparations in quick succession. I rebuilt the racks out of soldered copper tubing and drum stand parts. The Unit could be disassembled, collapsed and fit into trap cases for transport. In order to take up the space between the sounds, I developed what I called "travelling sounds." These were the sounds of one-handed instruments, or "blowpipes" as I came to call them, made of various lengths and diameters of PVC pipe with different sizes of saxophone mouthpieces and a tone hole or two in each. I could pick them up, play them with one hand, change preparations of the saxophone with the other and then put them down and be on to the next sound. I had a tenor blowpipe with a tenor mouthpiece and a two-piece variable-length sliding one of 3/4" PVC pipe ... a trombone-like blowpipe. The other instrument was a soprano blowpipe: a soprano mouthpiece on a short piece of 1/2" PVC. I also found that I could use the blowpipes as neck extensions on the tenor and soprano saxophones resulting in interesting multiphonic effects. This led to my extending the saxophones and solving my other problem of the mobility of the Unit. I built a vacuuphone extension (a vacuuphone in a large loop, placed on the neck of the tenor and fitted with a baritone saxophone mouthpiece). With this I found I was able to get very low tones from the tenor, and I subsequently jettisoned the bass sax from the Unit. Putting various mutes in the bells of the horns in combination with various extensions also revealed some interesting new sounds.

At this point, I was still playing completely acoustically. This limited whom I could play with, as my muted sounds were increasingly small and private. In addition, I was looking for more layering and density of sound in my performance. With the advent of digital sampling devices, I began to see the possibility of creating overdubbed sounds live in concert. I bought my first Electro-Harmonix Instant Replay Unit for this purpose in 1983. It wasn't for another 3-4 years that I was finally satisfied with my development of the electronics within the Unit. At first I was dissatisfied with having merely one looping device and found it much too limited and predictable. And so I added another device with overdubbing capacities and up to 4 seconds of memory, an Electro-Harmonix Super Replay. Soon thereafter, I added a cassette machine with a noise gate trigger which I would trigger with my feet (the samplers would also be triggered by feet). Originally I played ethnic music tape loops in my cassette, but later I used only my own sounds. I recorded a "vocabulary tape:" snippets of my personal vocabulary, kicked in to surprise me and spur me on to new playing ideas. Meanwhile, I had to develop a system of miking all these sounds to make them accessible to the sampling devices. By the time I had finished in 1986, I had placed a total of 7 small condenser mics on the ends of all the vacuuphones and on certain mutes. I used three SM-57 area mics, all on long goosenecks to be moved quickly to the appropriate place in the Unit (one for the tenor area, one for the soprano area and one for the mutes on the soprano rack). Finally, I had rigged up various mixers and switching boxes so that all the miked sounds were fed through the mixers' effects sends, out to either sampling device (now the Super Replay and an Electro-Harmonix 16 Second Digital Delay Unit) to be recorded on one of the two loops with the push of a footswitch, sent back to stereo channels of my mixer and replayed with the kick of a foot trigger. In addition to providing the greater density of sound I had been seeking, I found that this set-up solved the problem of volume. I was now able to play in many more venues and with many more collaborators.

But I also found myself precariously jumping from sound to sound, feeling frighteningly close to "out of control." At this point I decided to stop changing the instrument for a while, and, instead, to really learn to play it. Within a year, I felt that I was able to physically navigate my way within the set up. I was no longer embarrassed by the movement, feeling like a bull in a china shop, wondering what I would knock over next. But instead I began to find that the movement within the set-up was becoming an integral part of the performance. A hand flick here, a jump there, a fake to the left or the right, a head jerk in response to a surprising loop ... all of this became a window into how I felt about the sounds I was playing and the aural spaces I was leaving. And where earlier I had mourned the loss of physicality in my saxophone playing as I became wrapped up in decisions of which pedal to kick, which buttons to push, etc., I now found a totally new and different physicality as I became comfortable playing within the set-up.

Presently, although I am in a period of less rapid change with the instrument, the necessity continues for me to change the music and grow via instrumental changes. I never know where these changes will lead me. Lately I have been thinking about redesigning the Unit so that it is more

modular, in order, for example, that I might play a concert only on the tenor with the mutes that are used in it. I continue to fantasize about cutting my soprano in half so that it is truly a one-handed instrument. I think about taking the bell off the tenor in order to mute and prepare it more efficiently. I think about constructing a travelling unit in which the saxophones used are the much smaller alto and sopranino. I continue to fantasize about the slide saxophone I would like to build someday. And I even think about completely getting rid of the saxophones within the set-up and playing only the invented and found instruments -- thereby taking one step further towards complete sound-personalization.

In the more high-tech, electronic mode, I have begun to use multi-effects processors in conjunction with my saxophones (without mutes) in order to facilitate quick timbral changes electronically in much the same way that my mutes have done acoustically in the past. And I have somewhat trepidatiously moved in the direction of synthesizers, having recently bought a Casio F210 sampler and a Yamaha WX7 wind driver. I have begun to sample my acoustic vocabulary and trigger it with the WX7.

The process is hopefully a never-ending one. Although I have developed a certain style or musical trademark, I feel that it is absolutely essential to continue to grow and change. I have always looked to instrument modification as my way to do so. And I imagine that this will continue to be my means towards growth in the future.

Tom Guralnick's most recent solo recording, "Sonistruction" is available from UBIK SOUND, P.O. Box 4771, Albuquerque, NM 87196 or from Tom at 2512 Kathryn SE, Albuquerque, NM 87106, phone (505)842-5651. He welcomes inquiries of any sort: about concerts, about recordings, or just to talk.

PERCUSSION AEROPHONES

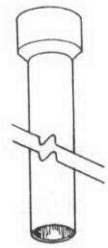
Continued from page 1

is that of a cylindrical tube (instruments made by the From Scratch ensemble, to be discussed in EMI's next issue, fit this description). Tubes are widely available in various sizes and materials, and they can easily be tuned by adjusting their lengths. Assuming the diameter is not too great, you can sound a tube by striking the end with your open hand. A tuned set of end-struck tubes makes for a very effective instrument.

Tubes used for aerophonic instruments in general can be open at both ends or closed at one end.[1] Cylindrical tubes that are closed at one end will resonate at a frequency approximately half that of tubes open at both ends, producing a sound about an octave lower for the closed tube.[2] Percussion aerophones can be made with either open or stopped tubes. Furthermore, tubes which are open at both ends can be made to act like stopped tubes in performance. Here's how: If you are playing with bare hands, clump your open hand down over the tube end in such a way that it covers the opening completely. Don't lift your hand immediately, but keep it in place for the duration of the tone. You will have, in effect, stopped the tube. The resulting pitch, accordingly, will be the stopped tube note in the lower octave. If you strike the same tube in such a way as not to cover the end (with flat fingers instead of the all-covering palm, lifting your hand immediately), you will hear the open tube pitch, about an octave higher. You can even create an upwardly bending tone by striking so as to fully cover the end, but lifting your hand as the tone still sounds, causing the pitch to try to bubble up to the upper octave before its brief burst of energy is dissipated.

Quite inconveniently, the octave difference between the closed tube tone and the open tube tone is not a true octave. The upper tone is a snoodgeon flat. While length is the most conspicuous factor determining the pitch at which a cylindrical tube will speak, another factor is the size of the aperture at the end of the tube. It is this open-end factor that throws off the octave relationship. The discrepancy is big enough that one can't use the same set of cylindrical tubes as upper and lower register in a single instrument.

There is a way around the problem, although it entails some ingenuity and craftspersonship. The technique was devised by the French maker Jacques Dudon. As the acoustics of the situation work, the narrower the aperture, the flatter will be the open tube pitch. Jacques has created tubes which abruptly become broader near the percussion end. The abrupt broadening effectively shortens the sounding length of the open tube, while the larger opening mitigates the open-end factor. The open tube pitch is raised, and the two tones sound a true octave. (More on Jacques' instrument below.)



Several different ways for exciting a body of air by percussion have proven effective. As described above, striking open tube ends directly with the hands works well, because hands are such sensitive and adaptable tools for tasks like this. Alternatively, in Papua New Guinea (and perhaps elsewhere in the Pacific?) a percussion aerophone playing style has evolved using broad, flat, moderately soft beaters. Coconut husks were used at one time; more recently the flat surface of beach thongs (the familiar rubber sandals) has come into favor. The heavy, soft rubber is rigid enough for a controllable stroke, but soft enough to damp the idiophonic sound of bat against tube edge. The thongs also have the advantage that they can cover a wider tube end than could the bare hand, and they are less likely than bare flesh to complain at the beating they take. The members of From Scratch use bats of a similar laminated rubber, described in their article following this one.

Flautists sometimes use aerophonic percussion on a smaller scale. If you deliberately slap the flute fingerhole pads closed with more than the usual force (not blowing at the same time), this gives the air in the flute a jolt, and produces a delicate percussive tone. Air percussion is extra fun with flutes because you can control pitch by selectively covering or uncovering the other holes before each pad-tap. Robert Dick, among others, has become a master of this technique.

Jacques Dudon's instrument mentioned above is sounded not by the slap of a hand or a beater, but by an encounter between water and air. The tube is large, open at both ends, with a larger mouth at one end as described above. The player dunks the large end a short distance into the drink, thus abruptly closing the aperture with a wall of water. This generates a slightly wobbly but definitely-pitched tone at the lower octave. When the player lifts it out, the tube abruptly opens again, and now the upper octave sounds. The two motions together make an appealing "goo-eenk?" sort of sound. From Scratch's Phil Dadson has devised several sliding tube percussion aerophones, one of which also uses water. An outer sleeve, in the form of a tube slightly larger than the main sounding tube, has a closed end and holds water. The main tube moves in and out within the outer to control pitch, and is sounded by striking its open end.

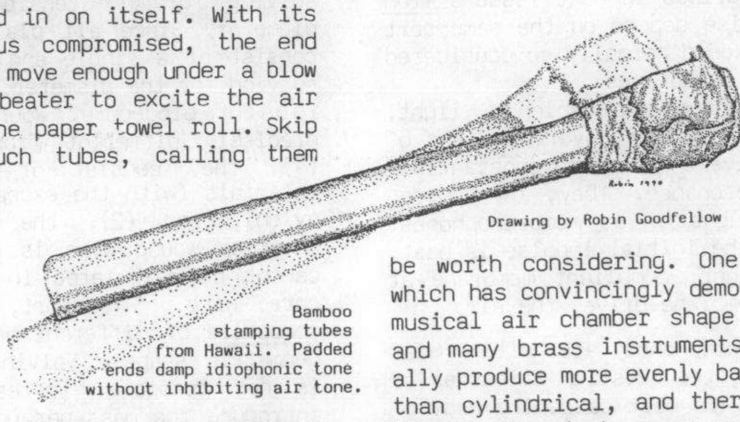
Another way to excite the air inside an enclosed chamber is to strike the surface of the chamber, giving it a jolt which in turn jolts the air within. This works nicely if the walls of the chamber are soft enough to give under the blow and thus communicate the impact to the air. You can hear this effect using the cardboard tube from a

1. You can have periodic vibrations in pipes closed at both ends as well, but they're less useful since the listener is walled off from the enclosed sound.

2. Cylindrical tubes open at both ends act as half-wave resonators, meaning that when the air in the tube oscillates at its fundamental resonant frequency, about one half of the wavelength is enclosed in the tube. Tubes closed at one end are quarter wave resonators, enclosing only one fourth of their fundamental resonance wavelength. Thus, a stopped tube will naturally resonate at twice the wavelength of an open tube of the same length. That translates to half the frequency for the stopped tube.

roll of paper towels. If you tap the side of it against a table edge or the base of your palm, the definitely-pitched tone of the air resonance will be the predominant component in the overall sound (the idiophonic cardboard sound will be present but, ideally, quieter).

In light of this, longer and heavier cardboard tubes, such as the ones used in storing bolts of fabric, begin to look very tempting. It turns out that they will work too, but not without some preparation. The walls of the heavier tubes are too firm to give under any but the most destructive blows, so all you hear when you strike them is a dull, unpitched cardboard sound. Skip La Plante, of the group **Music for Homemade Instruments** creates a softer area at one end of the tube by crushing the cardboard in on itself. With its structural integrity thus compromised, the end portion of the tube will move enough under a blow from a moderately heavy beater to excite the air in the tube, much like the paper towel roll. Skip makes tuned sets of such tubes, calling them Carimbas (= cardboard marimbas) [See his "Music for Homemade Instruments," EMI Vol.IV #1].


Drawing by Robin Goodfellow

Bamboo stamping tubes from Hawaii. Padded ends damp idiophonic tone without inhibiting air tone.

I have achieved the same effect myself by using the heavy ends of drumsticks to continuously batter one spot on the surface of a heavy cardboard tube until it begins to soften up under the repeated blows. In the early stages of the softening process, the dull cardboard sound dominates. It is a great pleasure to hear the clearly pitched musical tone slowly emerge as the cardboard gradually softens and more air moves with each blow. The softening done, all you have to do is remember to strike the tube in the pre-softened spot when you play. I made and mounted a tuned set of such tubes, possessing a three octave chromatic range and terrific volume, and called it the fabric shop toombah.

Some brands of caulk come in tubular plastic containers with nozzles, intended for use in caulking guns. These tubes, once empty of caulk, make great percussion aerophones sounded, like the cardboard tubes, by striking the side of the tube with or against something. The plastic makes relatively little noise, and the more musical air resonance sound comes across nicely. If you are content with just two pitches, you can hold a tube in each hand by the nozzle end, and strike them against a table edge while doing Latin dance steps. Members of From Scratch similarly use polythene golfbag tubes cut to length. In Part I of "Pacific 3,2,1,0," a nuclear protest piece, a range of these tubes are rhythmically sounded on the performers' thighs to accompany singing.

Tubes or globular chambers whose walls are too rigid to give under the force of a blow may still work well if they can be struck in such a way that the idiophonic tube sound does not overwhelm the air sound. Stamping tubes, used in traditional music cultures in various parts of the world, work this way [see EMI Vol. III #2; "'Au ni mako"]. A large, heavy tube of wood, bamboo or plastic (metal is likely to clank too much) can produce a satisfying, definitely-pitched bass resonance when tamped firmly, edge-on, on a solid surface. Smaller tubes can work as well. Darrell DeVore's Bootoo are short lengths of bamboo (8 - 12 inches or so) closed at one end by a natural node. He makes tone holes along the tube which he opens and closes, flute-like, with his fingers, as he plays the tubes in pairs, tonking them end-on against a stone to create the melodies of a babbling brook [see Darrell's "Bamboo is Sound Magic" in EMI Vol. III #4]. If you have the opportunity, see stamping tubes played superbly by the late master musician 'Irisipan in the film "Musique Are' Are" by Hugo Zemp, a wonderful documentation of the bamboo music of Malaita in the Solomon Islands.

Thus far we have spoken of percussion aerophones in two basic shapes: globular (roughly), as with the hand-struck jar or jug, and cylindrical, as with various sorts of tube instruments. Taking a cue from standard wind instruments, at least two other aspects of form might be worth considering. One is the conical tube, which has convincingly demonstrated its worth as a musical air chamber shape in saxophones, oboes, and many brass instruments. Conical bores generally produce more evenly balanced overtone spectra than cylindrical, and there's no reason to think they would not do so as well in an air column excited by percussion rather than breath and reed (bearing in mind that selecting the best point for excitation might prove more crucial for a conical bore). The second possibly promising formal element is the addition of a flared end -- that is, a bell -- on either a conical or cylindrical tube. The bell on a brass instrument serves to modify how much and which frequencies of the sound wave in the tube are reflected back into the tube at its opening point, thus helping perpetuate the standing wave. The flare tends to allow more of the high frequencies to make their way out of the tube and into the surrounding air, brightening the overall sound. Bell-less cylindrical tubes without side holes tend to have a slightly muffled, sewer-pipe kind of sound -- and this indeed is often characteristic of percussion aerophones tubes. Adding a bell might make for a more open tone quality. Phil Dadson has recently made an instrument using a spun aluminum bell attached to

Sliding pipe drum with flared end, played by Phil Dadson of From Scratch.

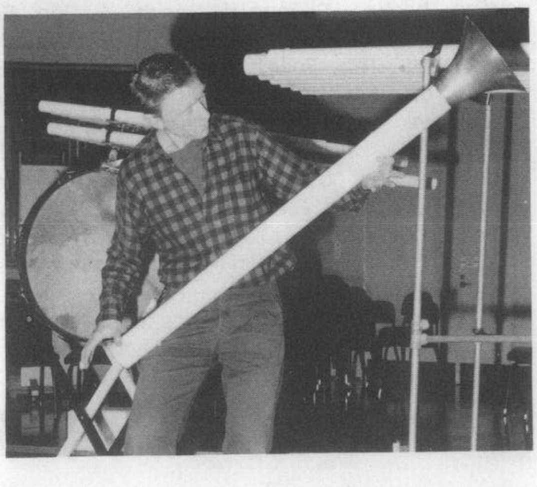


Photo by Stuart Souties

a length of PVC pipe. This sleeves snugly into another pipe with a diaphragm at the bottom end. The inner pipe slides up and down to produce a range of pitches -- fixed and sliding -- while the bottom end is hand struck.

Similar to the percussion aerophones described here are percussion instruments in which a body of resonant air is excited by a tuned element of some sort. Marimbas with tube resonators, for instance, take advantage of the same sort of air resonance. Such instruments aren't normally thought of as aerophones, because in them the bars, not the air, are the initial vibrating body and a predominant component of the sound. Partchian Boos, and the very similar tuned tongue bamboo instruments described in next issue's From Scratch article, likewise depend on the same sort of air resonance, but would normally be considered idiophones rather than aerophones.

Similarly, balloon drums (in which a light, thin membrane of balloon rubber covers the end of a tuned tube) also derive their sound substantially from tuned air resonance. They, of course, would normally be thought of as membranophones. But notice that, once the initial impulse is past, the air drives the light, compliant membrane at least as much as the membrane drives the air.

Since percussion aerophones are often most effective in tuned sets, the question arises as to how best to mount them. In most cases the body of the instrument can be held fast in just about any way that seems convenient, without damping the vibration. But, since they are usually struck and struck hard, a problem often arises with transmission of the striking impact to the framework that holds the sounding elements, adding an unwanted thud to the sound. In such cases, either padding or some sort of suspension mounting system can reduce the unwanted transmission. The key is to find a mounting system that is firm and stable enough for powerful playing and at the same time has the needed shock absorbing capacity.

Percussion aerophonics is a simple and effective means for producing musical sound, and many individuals and peoples have come across the idea and subsequently incorporated it into their music making. Several who have done so have already been mentioned in the course of this discussion. Others have touched on the subject in previous articles in EMI. Stamping tubes and related instruments appear in several home-made instrument making books. Reinhold Banek & Jon Scoville's classic instrument making book **Sound Designs** (Berkeley: Ten Speed Press, 1980) includes designs for a set of gloriously long hand-struck tuned percussion aerophone pipes, christened Po Pipes. Frank Giorgini's UDU Drums, and the Nigerian side-hole pot drums on which they are based, also fit the description beautifully [see EMI Vol. V #6]. One other truly outstanding use of the principle has been in instruments made by the group UAKTI, a Brazilian ensemble whose members play a variety of instruments of their own design. Their music is available on record. Very powerful stuff -- if you get a chance, give it a listen.

WOUND STRING CALCULATIONS

by Cris Forster

Readers of my previous article entitled "Plain String Calculations" may recall that the (F) frequency equation was written as:

$$F = \frac{1}{LD}\sqrt{\frac{GT}{\pi S}}$$

I then proceeded to write three more equations solving for (T) tension, (L) length, and (D) diameter. Since all plain strings by definition consist of a single and smooth uniform material, solving for the diameter is a straight forward and relevant procedure. Wound strings, however, are precisely different from plain strings because (1), they consist of two or more different materials (with the exception of nylon wound over nylon), and (2), the coiled surface of the exterior wound wire is not smooth and therefore cannot be calculated in the same manner as the core wire. In short, wound strings are a composite of different materials and of different geometric shapes. Solving for the diameter here is not possible. Instead, it is necessary to introduce the mass per unit length quantity. This single variable combines all the unique features of the above mentioned composite. Before analyzing this crucial M/u.l. quantity, here are the four equations for wound strings:

$$F = \frac{1}{2L}\sqrt{\frac{T}{M/u.l.}}$$

$$T = (2\ F\ L)^2\ M/u.l.$$

$$L = \frac{\frac{1}{2}\sqrt{\frac{T}{M/u.l.}}}{F}$$

$$M/u.l. = \frac{T}{(2\ F\ L)^2}$$

The practicality of this last equation with respect to wound strings is doubtful. I include it only to make the set complete.

In the case of wound strings which have a round, circular shape, (not flat wound strings), the M/u.l. variable actually represents the following subequation:

$$M/u.l. = \frac{\pi\ r^2\ S}{G}$$

This quantity must be found prior to calculating any of the first three equations listed directly above. This equation describes the solid cylindrical shape of the core wire and, (in conjunction with another set of calculations), the hollow cylindrical shape of any subsequent nylon fiber bedding or wound wire(s) layered over the core. Before all the variables and constants in these equations can be combined for a solution, they must first be expressed in units of measure that are consistent with one another. In the

English FPS system, mass is measured in foot-pound-second units. The resulting mass quantity is called a slug, as in slug per foot. However, measuring string lengths, string diameters, and wire diameters in foot units is not very useful or desirable. Therefore, with the exception of F and Pi, all measurements are given in inch/pound units, and the subsequent mass quantity will result in slug per inch.

General Equations:

F = Frequency, in cycles per second
T = Tension, in pounds of force
L = Effective vibrating string length, in inches

M/u.l. Subequation:

π = Pi, a constant, rounded off to 3.1416

r = Radius, also written as the diameter divided by 2, (D/2), in inches

G = The acceleration of gravity, a constant, given as 32.2 ft/sec^2. Since all linear measurements are here expressed in inches, the value 32.2' * 12" becomes 386.4 inches/sec^2.

S = Weight per unit volume for a given stringing material, in pounds per cubic inch. The weights for eight common materials are:

Material	Weight/Volume
Nylon	.038 lb/in^3
Aluminum	.098 lb/in^3
Steel	.283 lb/in^3
Bronze	.320 lb/in^3
Nickel	.322 lb/in^3
Copper	.323 lb/in^3
Silver	.379 lb/in^3
Tungsten	.697 lb/in^3

I would now like to discuss the composite of a wound string made of three different materials: a solid steel core, an interior nylon fiber bedding, and an exterior bronze wrap. The nylon fibers provide a soft surface around the steel core. Without this bedding, the bronze wrap would begin to unravel, causing the string to either buzz or to go dead.

FIGURE A

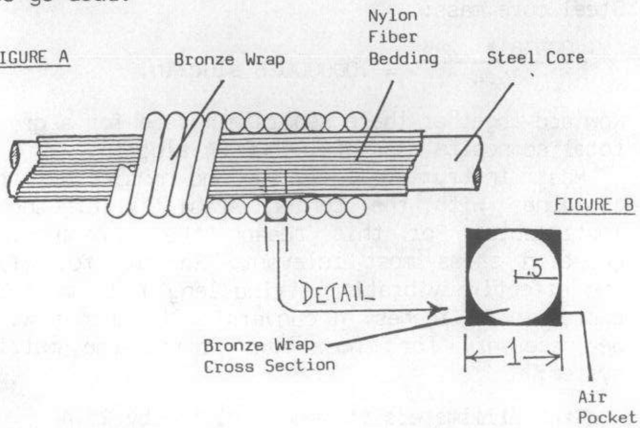


FIGURE B

Figure A shows the longitudinal cross section of this string. Unlike the solid smooth surface of the core, and the stranded smooth surface of the nylon fiber bedding, the windings of the wrap resemble the coiled profile of a spring. The shaded areas between individual coils indicate air pockets devoid of any winding material. Figure B shows a detailed transverse cross section of one such coil and four air pockets in each corner. By subtracting the surface area of the circle from the surface area of the square, it is possible to determine the proportional relationship between winding material and air. The area of the unit square, $1^2 = 1$. The area of the inscribed circle, $.5^2 * \text{Pi} = .7854$. Since 1 - .7854 = .2146, we conclude that the winding occupies 78.54% of the area, and the air 21.46%. The table above gives the weight of bronze as .320 lb/in^3. Multiplying this amount, .320 * .7854 = .2513 lb/in^3, the modified weight for the exterior bronze wrap. This new weight will be substituted for (S) in the M/u.l. subequation.

The next step is to analyze the two different geometric shapes of the proposed wound string. Consider two small tubes, one larger in diameter than the other, fitted tightly together like a telescope joint, and slipped over one of your fingers. The finger represents the steel core, and it is always in the shape of a solid cylinder. The tubes represent the inner nylon bedding and the outer bronze wrap, and they are always in the shape of hollow cylinders.

To find the composite M/u.l. of the wound string example, we must make a separate calculation for each of the three materials in question before adding them together for a grand total slug/in. result. First, however, I would like to explain M/u.l.. Unit length refers to a 1 inch length of string, or, in this specific case, a 1 inch length of two hollow cylinders and one solid cylinder. The mass is defined by:

$$M = \frac{W}{G}$$

where (W) refers to the simple weight of a given object. To calculate the weight of any three dimensional object, multiply:

(Cubic volume) * (Weight per Unit Volume) = W

The numerator on the right hand side of the original M/u.l. subequation states exactly the same thing:

$$\underline{(\pi\ r^2) * (1)} * (S) = W$$

The inclusion here of the number 1 will be explained below.

Since we know (S) for eight different materials listed in the table above, the question remains how to find the cubic volumes. We begin by inspecting a cross section of the two different kinds of cylinders. The solid core cross section is in the shape of a circle. The hollow tubular cross sections are in the shape of rings. We now

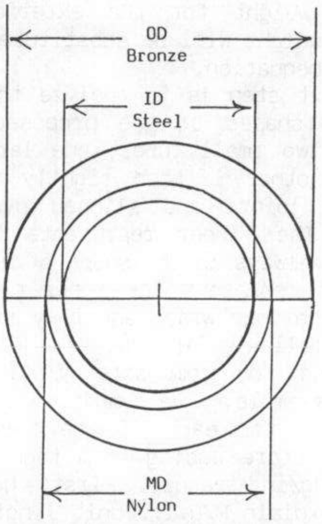
calculate the flat surface areas of one circle and two rings because:

(Ring or circular Area of cylinder) * (Length of cyl.) = Cubic Volume of cylinder.

The final step which transforms these two dimensional areas into three dimensional volumes requires that we multiply them by 1 inch, the unit length of either string or cylinder. However, since multiplying by 1 does not change the numeric result of the areas, further calculations are not necessary. Although the actual unit length quantity never appears, its functions are both critical and convenient.

It is common practice to write equations for the areas of circles and rings with a radius (r) variable. See the above M/u.l. subequation. Here, however, it is simpler to find the areas with diameter dimensions. Consequently, all the diameters shown below must first be divided by 2 before the result, (the actual radius), can be squared.

FIGURE C



Since we are considering three different materials, we must consider three different diameters as well. Figure C shows a cross section of how these materials are distributed: The outside diameter (OD) includes the entire cross section from the string's center to the outer bronze wrap; the middle diameter (MD) includes the inner two sections from the center to the nylon bedding; the inside diameter (ID) includes the central steel core. For the area of the core circle, calculate Pi * $(ID/2)^2$. The ring areas are found by subtracting the areas of the small circles from the areas of the large circles. For the area of the larger outer ring, subtract the (MD) area from the (OD) area:

$$\begin{array}{l} \text{Pi} * (OD/2)^2 \\ \underline{- \text{Pi} * (MD/2)^2} \\ \text{Outer Ring Area} \end{array}$$

And for the area of the smaller inner ring, subtract the (ID) core area from the (MD) area:

$$\begin{array}{l} \text{Pi} * (MD/2)^2 \\ \underline{- \text{Pi} * (ID/2)^2} \\ \text{Inner Ring Area} \end{array}$$

We are ready now to find the M/u.l. variable by considering actual dimensions of a wound string sample. (Since the soft layer of the nylon fiber bedding cannot be measured with a micrometer, we determine the middle diameter (MD) indirectly.) But first, here are the three dimensions of the materials that can be measured:

Total outside diameter (OD):	.044"
Diameter of the steel core (ID):	.022"
Diameter of the bronze wrap wire:	.007"

Because a wrapped wire expands the unwrapped diameter of a given string by twice its own diameter, determine the (MD) by multiplying the wrap wire diameter times 2, and then subtract it from the (OD):

$$\begin{array}{rll} & .044" & (OD) \\ - & \underline{.014"} & (.007 \times 2) \\ (MD) = & .030" & \end{array}$$

Finally, the area of the outer ring equals:

$$\begin{array}{l} \text{Pi} * (.044/2)^2 \\ \underline{- \text{Pi} * (.030/2)^2} \\ .00081 \text{ sq. in.} \end{array}$$

And the area of the inner ring equals:

$$\begin{array}{l} \text{Pi} * (.030/2)^2 \\ \underline{- \text{Pi} * (.022/2)^2} \\ .00033 \text{ sq. in.} \end{array}$$

The area of the core circle equals:

Pi * $(.022/2)^2$ = .00038 sq. in.

Looking back to the M/u.l. subequation, we have now accounted for the area requirements (pi * r^2) for two rings and one circle. To determine the three separate masses, multiply (theoretically) each area by 1 inch (gives volume), multiply again by the weight (S) for each of the three materials (gives weight per volume), and divide by the acceleration of gravity (G) (gives mass per volume). Remember that the weight (S) for the bronze wrap was modified from .320 lb/in^3 to .251 lb/in^3.

Bronze wrap mass:

$$\frac{.00081 * .251}{386.4} = .00000053 \text{ slug/in.}$$

Nylon bedding mass:

$$\frac{.00033 * .038}{386.4} = .00000003 \text{ slug/in.}$$

Steel core mass:

$$\frac{.00038 * .283}{386.4} = .00000028 \text{ slug/in.}$$

Now add together these separate masses for a grand total composite mass of .00000084 slug/in.

Most instrument builders and musicians are concerned with the tuning stability of their instruments. For this reason the (T) tension equation seems most relevant. Solving for (T), the effective vibrating string length (L) must be expressed in inches. A conversion to inches will be necessary for those who prefer the metric system:

From millimeters to inches divide by 25.4
From centimeters to inches divide by 2.54.

(continued at right below)

CONCEPTUAL INSTRUMENTS

By Douglas Kahn

Douglas Kahn, audio artist and writer, is co-editor with Gregory Whitehead of Wireless Imagination: Sound, Radio and the Avant-garde (forthcoming from M.I.T. Press) and teaches at the Inter-Arts Center, San Francisco State University.

You've heard of music theory but have you heard theoretical music? It is performed for the inner ear by instruments built of idea alone. The instrument makers mentioned in this essay are residents of the avant-garde from the late-nineteenth century to the time of World War I: the French writers J.K. Huysmans, Auguste Villiers de l'Isle Adam, Raymond Roussel and Guillaume Apollinaire and the Russian writer Velimir Khlebnikov. The instruments they describe are: (1) possible to physically construct but the sound is impossible or incongruous; (2) impossible to construct but the sound is possible; or (3) both the instrument and sound are impossible.

However, the word **impossible** always carries a threat of its own destruction. The experimental nature of these instruments, where experiment can proceed unfettered by any practical constraints, can easily portend a practical technological implementation where the impossible becomes merely improbable, e.g., the organ in Apollinaire's story "The Moon King," described later in this article. The important practical benefit of conceptual instruments, however, is how, by performing for the inner ear, they stretch listening abilities. From these abilities will the limits of composition, performance and instrument construction be tested. For instance, Marcel Duchamp, in his personal notes, proposed creating profiles and sculptures of sound in space around and about the listener. The immediate impulse is to ask whether or how these profiles and sculptures might be technologically constructed. Duchamp instead suggested that it would not be, first of all, an advanced technology that would allow the listener to perceive and appreciate the these sonic forms, but rather an advancement in learning how to hear, a perceptual training that would carry forth over generations:

> Develop: one could, after training
> the listener's ear, succeed in
> drawing a resembling and
> recognizable profile -- with more training
> make large sculptures in which
> the listener would be a center -- For ex.
> an immense Venus de Milo made of sounds
> around the listener -- This probably
> presupposes an aural training from
> childhood and for several generations.
> ...after the Venus de Milo there would
> be an infinity of other transformations
> more inte[resting] ... [1]

Conceptual instruments should not be considered only in their relationship to practical realization, whether technological or perceptual. To peg the performances of the psyche to any pragmatic concern is something of an invasion of privacy. After all, we constantly hear the claim that music plumbs the depths of the soul. Yet we are not only a drain. The pipes for this plumbing flow both ways, and they do not hum and knock and wheeze and whistle according to physical/acoustic laws. When people die, those witnessing hear only the anticlimactic gurgling of the death rattle, while the dead person is being entertained with the first strains of celestial harmonies. The inner ear with which we hear the performances of conceptual instruments varies considerably from our physiological ears. We are equipped with two outer ears on either side of our heads to locate sonic events and movement within acoustic space. The inner ear is not singular and cyclaurical, however; it's twin is one more step in. This puts conceptual binaurality on another axis altogether, serving not to locate but to fathom. It is only reasonable, therefore, to build instruments for performance under these specific conditions. Doing so has the advantage of circumventing all the nagging requirements of securing a time and date and arranging publicity for a performance. The only boomy acoustics are cranial, the only power failure synaptical. And there isn't a bad seat in the house.

One of the earliest bloomings of conceptual instruments occurred among the French Symbolists and was informed by principles of synaesthesia. Synaesthesia posits the correspondences of the senses, e.g., color relates to sound and vice versa, sounds to olfactory and tactile sensations, etc. Ideas of synaesthesia in the arts derived variously from physiological (the finding earlier in the nineteenth century that different stimula produced the same sensation in a given sensory nerve), metaphysical and musical sources (chromaticism). Ernest Cabaner, barman and piano player at the Cercle Zutique founded by Charles Cros (poet and inventor of a pre-Edisonian phonograph), told the poet Villiers: "There is a relationship

Wound Strings, continued from page 16

The wound string sample mentioned above is a string I designed for my Bass Canon. The lengths of the strings are 120 cms (or 120/2.54 = 47.244 inches), and the strings are tuned to 98 cps. Solving then for (T) tension:

$$T = (2 * 98 \text{ cps} * 47.244 \text{ in})^2 * .00000084 \text{ slug/in.}$$
$$T = (4 * 9{,}604 * 2{,}232.0) * .00000084$$
$$T = 71.8 \text{ lbs.}$$

In conclusion, it should be stated that the outer wrap of a wound string contributes nothing to the tensile strength of the core wire. To determine the break strength of a given core wire, please refer to my previous article "Plain String Calculations", EMI Volume V, #6, April 1990.

between the gamut of sounds and the spectrum of colors. Long study has brought me to the conclusion that white must correspond to **do**, blue to **re**, pink to **me**, black to **fa**, green to **sol.** When the relationships between colors and sounds have been found, music may be translated into landscapes and portraits by replacing the colors, and by marking the halftones with sharps and flats."[2] A piano student of his named Arthur Rimbaud, in his poem **Voyelles**, attributed certain vowels to certain colors: "**a** black, **e** white, **i** red, **u** green, **o** blue." Rene Ghil played with a different spectrum and then went one step further by adding a corresponding musical instrument in his **Verbal Instrumentations**: "**a**, black, organ; **e**, white, harp; **i**, blue, violin; **o**, red, brass; **u**, yellow, flute." The most accomplished synaesthetic instrument builder, however, was J.K. Huysmans, who supplied the decadent protagonist of his famous 1884 novel **A Rebours** with a synaesthetic **mouth organ** built of a row of small liquor casks. Each cask was equipped with a silver spigot and labeled as a musical instrument, e.g., flute, horn, vox humana, etc. The performance was intoxicating:

> Des Esseintes would imbibe a drop here, another there, another elsewhere, thus playing symphonies on his internal economy, producing on his palate a series of sensations analogous to those wherewith music gratifies the ear.
>
> Indeed, each several liquor corresponded, so he held, in taste with the sound of a particular instrument. Dry curaçao, for instance, was like the clarinet with its shrill, velvety note; kümmel like the oboe, whose timbre is sonorous and nasal; crême de menthe and anisette like the flute, at one and the same time, sweet and poignant, whining and soft. Then, to complete the orchestra, comes kirsch, blowing a wild trumpet blast; gin and whisky, deafening the palate with their harsh outbursts of cornets and trombones...[3]

Just a few years before the publication of Huysmans' novel, fellow Frenchman Villiers de l'Isle Adam was serializing his **L'Eve Future** (1885).[4] The novel has been described as Jules Verne infused with poetry[5] but it is perhaps better described as the **Stepford Wives** infused with late 19th century misogyny. The novel features a fictional Thomas A. Edison who invents an obedient female gyndroid (female android) of Pre-Raphaelite beauty to prevent his friend of confused heart from committing suicide. Phonographs figure in throughout, most prominently as a pair of golden phonographs located at the gyndroid's lungs that operate as the source of her speech and intelligence. There are other phonographs in a scene where Edison and his friend descend deep down to an enormous subterranean Eden lushly populated with birds and plants. The birds aren't really birds but merely "winged condensers," phonographically equipped with "human voices and human laughter instead of the old-fashioned, meaningless song of the normal bird."[6] There is a swan that contains the voice of a famous opera singer, and a hummingbird that can recite Shakespeare's **Hamlet**; and the Bird of Paradise "...could give you, all by himself and with just as much intelligence as the united brains of all the singers whose voices are contained in him, a complete rendition of Berlioz's **Faust** (orchestra, chorus, quartets, soloists, encoures, applause from the audience, renewed applause, down to the vague, indistinct comments made by the listeners)....an immense volume of sound, worthy of an opera hall, would pour forth for you from this tiny rosy beak."[7] At one point the whole aviary becomes cacophonous with "Frightful squawking noises, as of random visitors, poured from the throats of the birds; they were cries of admiration, questions either banal or preposterous, ... laughter and applause, occasional deafening snorts as of noses being blown, offers of money."[8]

Sounds abound in the novels of the French writer Raymond Roussel, an uncanny occurrence for someone whose writing is known for its exhaustive and pristine visual description. To my mind the conceptual sonics of his two major novels, **Impressions of Africa** (1910) and **Locus Solus** (1914), are only matched in the psychotic account written by the late-nineteenth century Prussian judge, Daniel Paul Schreber.[9] In **Impressions of Africa** alone, we find a limbless one-man band, a candle whose sputter imitates the sound of thunder, a father who bounces vocal pyrotechnics off his emaciated sons' chests, a man playing a flute carved from his own tibia, the pitched wheels of twelve chariots performing "a variety of popular airs," the names of flowers echoing back accompanied by their respective scents, an orchestrion fueled by the expansion and contraction of a thermally sensitive metal, a hiccupping mollusk, a pre-Mr. Ed talking horse, a man who can simultaneously sing four different parts (outdoing Rahsaan Roland Kirk) from different parts of his enormous mouth, rodent hair that produced two distinct notes per strand when bowed, etc. Of particular interest in **Impressions of Africa** is the Hungarian Skariofszky who taught a huge, docile, and musically entranced worm, the inhabitant of a spring with water of unusually dense viscosity, how to play the zither. First Skariofszky built the worm a contraption suspended above the zither from which the worm would drop the heavy water of the spring onto the zither strings.

> The rocks in the river provided him with four sheets of solid yet transparent mica, which, trimmed and squared, then cemented together with clay, formed a receptacle adapted to the ends he envisaged. Two stout branches, vertically planted in the ground to either side of the zither, held between their forked extremities what was in effect a long, narrow trough, buddle, sluice-box or flume. Skariofszky trained the worm to slip into this mica receptacle; then, as it stretched out, to block up a groove cut along the lower groin. Equipped with a gourd, it did not take him long to draw a few quarts of water from the spring and pour them into the transparent sluice. Subsequently, with the end of a twig, he lifted for a quarter of a second, a minute portion of the extended body. A drop of water escaped and struck a zither string which gave out a clear note.[10]

Skariofszky raised the worm's body in a succession of notes forming a **ritornello.** The worm then twitched out the same phrase unassisted. In fact, the worm displayed a remarkable memory, learning "various lively or melancholy Hungarian tunes" with great ease. It also learned to secrete two notes at once, as though playing with a pair of

plectra and ..."In the end, multiplying the difficulties, Skariofszky tied a long twig to each of his ten fingers and taught the worm polyphonic acrobatics normally excluded from his own repertory."[11]

Guillaume Apollinaire, the French writer and critic, also had a large auricular chamber in his heart for sounds, as can be found in the "pop-up" sound in his graphic poem "Lettre-Ocean," the simulated phonographic recording in his "conversation-poems," the myriad of sounds in the play **Les Mamelles de Tiresias,** championing the pianocaust of Alberto Savinio, the punning and sounds in his pornographic writings, and his proposals for a phonographic art in perhaps his best known essay, "The New Spirit and the Poets." In his 1916 story "The Moon King" Apollinaire writes of a man who, having lost his way in the mountains, planned to spend a night in a cavern: "Outside the wind was howling and the soughing of the pines had something poignant about it, as if thousands of travelers were crying out in despair."[12] Then the distant sound of music draws him into the subterranean reaches of the mountain. Inside he follows behind a group of young hedonists, peering in on them, through a series of passageways and rooms. He eventually becomes witness to another set of sounds altogether emanating from a modern metallic room scented with roses. An elderly man regally dressed, later recognized as King Ludwig II of Bavaria, thought to be drowned, is sitting at an unusual keyboard instrument. The King presses a key, listens intently and then declaims theatrically:

> "Hermit kingdom! O Land of Calm Morning! The first blush of dawn on your territory and already the prayers are rising from your monasteries and this precise machine is bringing me the sound. I hear the rustlings of oil-paper vests, the kind commoners wear, and I hear the storm of alms raining down on the scuffling paupers. I hear you too, bronze clock of Seoul. In your voice I hear a child crying. I also hear a procession following its fine lord, the magnificent Yang Ban in his saddle..."[13]

The King then presses another key and, according to a similar set of pronouncements, Japan at dawn is heard.

> The flawless microphones of the king's device were set so as to bring in to this underground the most distant sounds of terrestrial life. Each key activated a microphone set for such-and-such a distance. Now we were hearing a Japanese country side. The wind soughed in the trees -- a village was probably there, because I heard servants' laughter, a carpenter's plane, and the spray of an icy waterfall. Then another key pressed down, we were taken straight into morning, the king greeting the socialist labor of New Zealand, and I heard geysers spewing hot water. Then this wonderful morning continued in sweet Tahiti. Here we are at the market in Papeete, with the lascivious wahines of New Cytheria wandering through it -- you could hear their lovely guttural language, very much like ancient Greek. You could also hear the Chinese selling tea, coffee, butter, and cakes. The sound of accordions and Jew's harps...14

Then a train in the U.S., urban noises of Chicago, vessels along the Hudson, prayers for Christ in Mexico, carnival in Rio, a teacup in Paris, a chorus in Bonn, hand games in Naples, and finally ten o'clock in Tripoli. Then the "king's fingers ran over the keys at random, simultaneously raising all the sounds of this world which we, standing still, had just toured aurally."[15]

Instead of the global spatiality of the Moon King's organ, the Russian Futurist poet Velimir Khlebnikov describes in his 1915 story "Ka" an instrument founded on temporal and historical principles. This needs some explanation. In the story, global space had been conquered; the future lay with time. For example, World War One was a war for territory and space; when an artist was asked in "Ka" whether he was headed for war, he replied, "I'm already at war, only it's a war to conquer time, not space. I crouch in my trench and grab scraps of time from the past. It's a rough assignment, just as bad as you'd have in a battle for space."[16] Historical time was the raw material for Khlebnikov's art, and for his secular system of divination based upon mathematics. His correlation of historical time and mathematics arose from his desire, while he was a student of mathematics, to explain the terrible defeat suffered by the Russian naval fleet during the Russo-Japanese War. To this end he generated a complex set of calculations mapping the temporal relationships of past events, as demonstrated in his "Tables of Destiny." It then was only a matter of extrapolation to travel into the future.

From this point, it was only a matter of correlating the mathematical basis of the laws of history and destiny with the mathematical basis of musical intervals, and to resurrect the Orphic union of poetry and music, to arrive at the oracular lyre in "Ka." Ka is a mythic figure, a time traveler capable of taking different forms, "the soul's shadow, its double, its envoy to the world some snoring gentleman dreams of."[17] Well into the story Ka is a bird flying near the source of the Nile, where he joins a circle of apes sitting around a fire reminiscing about the Roc bird. Then Ka fashions the lyre and asks a beautiful female ape to sing.

> Ka set an elephant tusk on end and at the top, as if they were pegs for strings, he fastened the years 411, 709, 1237, 1453, 1871; and below on the footboard the years 1491, 1193, 665, 449, 31. Strings joined the upper and the lower pegs; they vibrated faintly.

The female ape takes up the lyre and begins singing a song of the Fates.

> She moved her hand across the strings; they sounded the thunder boom of a flock of swans that settles as one body onto a lake.
>
> Ka observed that each string consisted of six parts, each part consisting of 317 years, 1902 years in all. And also that the top row of pegs indicated years when the East attacked the West, while the pegs at the lower end of the strings indicated an opposite movement, the West against the East. In the top row were the Vandals, Arabs, Tatars, Turks, and Germans; below were the Egyptians of Hatshepsut, the Greeks of Odysseus, the Scythians, the Greeks of Pericles, the Romans. Ka attached one additional string: between the year 78, the invasion of the Scythians of Adia Saka, and the

year 1980 -- the East. Ka studied the possibilities of playing on all seven strings.

The instruments mentioned here are only scattered examples of a rather large, complex and legitimate organological class. As with so much of the avant-garde sonic arts in general, conceptual instruments are in need of systematic study and exposure. Ideally, this will result both in the dramatic reformulation of actual musical instruments and an increased interest in and construction of conceptual instruments in their own right.

FOOTNOTES:

1. Marcel Duchamp, Notes, (Boston: G.K. Hall & Company, 1983), Note #183.
2. Cited in Pierre Petitfils, Rimbaud, translated by Alan Sheridan. (Charlottesville: University Press of Virginia, 1987), 118-20.
3. J.K. Huysmans, Against the Grain, (New York: Dover Publications, 1969), 44-46.
4. Villiers de l'Isle Adam, L'Eve future, translated as Tomorrow's Eve by Robert Martin Adams (Urbana: University of Illinois, 1982).
5. L'Eve Future directly informs Verne's Carpathian Castle (1892) which itself has its contemporary counterpart in the movie Diva.
6. Ibid., 93.
7. Ibid., 97.
8. Ibid., 94.
9. Daniel Paul Schreber, Memoirs of My Nervous Illness, translated by Ida Macalpine and Richard Hunter, (Cambridge: Harvard University Press, 1988).
10. Raymond Roussel, Impressions of Africa, translated by Lindy Foord and Rayner Heppenstall (New York: Riverrun Press, 1983), 271-72, see also 54-59 and chapter XVI.
11. Ibid., 273.
12. Guillaume Apollinaire, "The Moon King" in The Poet Assassinated, translated by Ron Padgett (San Francisco: North Point Press, 1984), 70-83. The spirit of global spatiality could be found later on in Varese's plans to write a work known variously as The Red Symphony, Space and Astronomy.
13. Ibid., 79.
14. Ibid., 80.
15. Ibid., 81.
16. Velimir Khlebnikov, "Ka" in Collected Works, Volume II, translated by a Paul Schmidt (Cambridge: Harvard University Press, 1989), 59.
17. Ibid., 56.

Books

FUNDAMENTALS OF MUSIC
By Boethius, Anicius Manlius Severinus

Translated with Introduction and Notes by Calvin M. Bower, Edited by Claude V. Palisca. Published in 1989 by Yale University Press (New Haven/London) in their Music Theory Translation Series. xliv + 205 pp., $32.50 list.

QUANTIFYING MUSIC: THE SCIENCE OF MUSIC AT THE FIRST STAGE OF THE SCIENTIFIC REVOLUTION, 1580-1650.
By Cohen, H. Floris

Published in 1984 by D. Reidel, University of Western Ontario Series in Philosophy of Science, Vol. 23 (Dordrecht/Boston/Lancaster); xvii + 308 pp. illus., biblio, index, $70.00 list.

In presenting the books that follow here, reviewer Charles Adams highlights a distinguished role that musical instruments played in the early development of scientific thought. In past centuries, when distinctions were less rigidly drawn between art and science, and between nature and spirit, important thinkers from Pythagoras to Kepler were drawn to increasingly empirical and mathematical inquiries into the nature of harmony and its physical basis. Over time these investigations served as one of the essential proving grounds in the evolution of scientific thought. The physical instruments of music played a central role here, and it is instructive to think about why: Musical instruments present a beautiful instance of nature simplified and controlled. As such, they make ideal **models.** This idea of modelling -- of extracting from the confusing complexity of nature a controlled, simplified replica of itself in order to formulate hypotheses and make verifiable predictions -- has been a fundamental element in the development of modern science. Standard musical instruments, as well as special apparatus like the monochord, were among the very first devices ever to be used thus; they were, in that sense, models for the developing concept of scientific modelling. In turn the laws of harmony and consonance thus derived served as models themselves for developing theories concerning the celestial bodies and other aspects of nature.

The books reviewed here deal with these developments. Our reviewer looks first at a new translation of a very early source, Boethius' **Fundamentals of Music**, and extracts from it a wonderfully quaint and curious story of Pythagorus' first forays into the empirical nature of consonance. He balances this with a modern scholarly work addressing the continuing developments, so long in incubation, that came with the Renaissance. These will be supplemented in EMI's next issue (due in December) with further notes from Charles Adams on a couple of related topics: a quick review of a new book on ancient Greek instruments, and some passages and diagrams from a turn of the century high school physics text, describing simple acoustical experimental apparatus suitable for use by latter day Pythagori.

Review by Charles Adams

FUNDAMENTALS OF MUSIC

Boethius' **Fundamentals of Music** (De institutione musica), written about 505 A.D., has been among the most durable and influential theoretical treatises of the western musical tradition. Boethius (c. 480-524 A.D.) was a Consul of Rome, and though he was imprisoned and executed by the Ostrogoth King Theodoric, **Fundamentals** survived in numerous manuscript copies, and was the keystone music-theoretic work, from the 9th to the 14th centuries. It was one of the first musical treatises to benefit from the printing press (in 1491), and it was listed as required university reading well into the 17th century. Only one published translation, in German from the original Latin (1872), preceded this new (and simply excellent) critical English edition.

Fundamentals is itself largely a translation of earlier Greek works: a lost **Eisagoge musica** (Introduction to Music) by Nicomachus, and parts of **Sectio canonis** and Claudius Ptolemy's **Harmonica**. It was "written for a cultural elite already initiated into philosophical literature. Boethius's mathematical and logical works represent one of the most notable projects in intellectual history of preserving and transmitting a corpus of knowledge from one culture to another" (Bower, Introduction, p.xx.)

Boethius's treatise contains little about musical instruments as such, nothing at all on their construction or performance techniques, but the work is, nevertheless, primarily about the "music of instruments," by which Boethius understood "the mathematical principles that determine the structure of classical systems" (Bower, Note 44, p. 10). Thus while Boethius had high regard for the passional art of music, **Fundamentals** concerns the rational science of music as one part of the quadrivium (along with arithmetic, geometry, and astronomy), and especially the science of the divisions of the stretched string. Music is, according to him, of three kinds:

"the first is cosmic (observed in heaven itself or in the combination of elements or the diversity of seasons), whereas the second is human (what unites the incorporeal nature of reason with the body); the third is that which rests in certain instruments, such as the kithara or the aulos which serve melody." (Boethius pp. 9-10).

Boethius recounted the oft-told tale of Pythagoras's 'discovery' of (and experiments with) the ratios of the primary musical consonances:

"The Pythagoreans estimate consonances themselves with the ear, but they do not entrust the distances by which the consonances differ among themselves to the ears, whose judgments are indecisive. They delegate the determination of distances to rule and reason[1] -- as though the sense were something submissive and a servant, while reason is a judge and carries authority. ... Pythagoras ... put no credence in human ears which are subject to change, in part through nature, in part by external circumstance, and undergo changes caused by age. Nor did he devote himself to instruments, in conjunction with which much inconsistency and uncertainty often arise. When you wish to examine strings, for example, more humid air may deaden the pulsation, or drier air may excite it ...

"Assessing all these instruments as unreliable and granting them a minimum of trust, yet remaining curious for some time, Pythagoras was seeking a way to acquire through reason, unfalteringly and consistently, a full knowledge of the criteria for consonances. In the meantime, by a kind of divine will, while passing the workshop of blacksmiths, he overheard the beating of hammers somehow emit a single consonance from differing sounds. Thus in the presence of what he had long sought, he approached the activity spellbound. Reflecting for a time, he decided that the strength of the men hammering caused the diversity of sounds, and in order to prove this more clearly, he commanded them to exchange hammers among themselves. But the property of sounds did not rest in the muscles of the men; rather, it followed the exchanged hammers. When he observed this he examined the weight of the hammers. ...Pythagoras was the first to ascertain through this means by what ratio the concord of sounds was joined together. So that what has been said might be made clearer, for the sake of illustration, let the weights of the four hammers be contained in the numbers below:

12 : 9 : 8 : 6

Thus the hammers which bring together 12 with 6 pounds sounded the consonance of the diapason (octave) in duple (2:1) ratio. The hammer of 12 pounds with that of 9 (and the hammer of 8 with that of 6) joined in the consonance of the diatessaron (fourth) according to the epitrita (1 1/3 or 4:3) ratio ...

"Upon returning home, Pythagoras weighed carefully by means of different observations whether the complete theory of consonances might consist of these ratios.[2] First, he attached corresponding weights to strings and discerned by ear their consonances; then, he applied the double and the mean and fitted other ratios to lengths of pipes. He came to enjoy a most complete assurance through various experiments. By way of measurement, he poured ladles of corresponding weights into glasses, and he struck these glasses -- set in order according to various weights -- with a rod of copper or iron, and he was glad to have found nothing at variance. Thus led, he turned to length and thickness of strings, that he might test further. And in this way, he found the rule..." (Boethius, pp. 17-19)

Had Pythagoras actually performed the experiments with weight-tensioned strings as Boethius describes them, he would not have enjoyed 'a most complete assurance' of the rules of rational consonances. Rather, since the frequency of a string is proportional to the square root of its tension, he would have heard the harshest of dissonances: weights of 12 and 6 pounds on strings (of equal length and mass) produce an interval difference of a tritone (600 cents = log 12:6 X (1200/log 1)). Nor are the hammer weight ratios valid except in coincidental cases, since there is no rule of linear relationships between mass and frequency in idiophones. The 12:9:8:6 ratios are valid, however, for ratios of string length or, inversely, frequency of vibration.

QUANTIFYING MUSIC

"Sounds can shed more light on Philosophy than any other quality, which is why the science of Music should not be neglected, even if all singing and playing were completely abolished and forbidden."

Marin Mersenne, **Harmonie universelle**, 1636

Cohen's meticulous historical study of the science of music from 1580-1650 is, in part, a

test case of certain theories of the historical development of science. Cohen refutes an earlier conjecture that experimental approaches to music actually precipitated the whole of the scientific revolution, but shows nevertheless that musical and acoustical questions were of broad concern to most of the early modern scientific figures. While **Quantifying Music** is devoted primarily to the problematics of consonance and dissonance in light of the emerging science of acoustics, the role instrumental experimentation is crucial.

Historians disagree as to what best characterizes the modern scientific revolution. Cohen appeals especially to the factors of quantified observations, experimental verification, and the use of simplified models, such as those derived from mechanics or geometry, for complex natural phenomena. (In those terms, it can be noted, the revolution took place in musical science some 200 years before it did in chemistry, which did not become rigorously quantified until the time of Lavoisier). Another emphasis is on the growing interactions between the practitioners of the various arts and crafts and those interested in theoretical explanations; the practical knowledge of the artificers, whether builders of fortresses or makers of musical instruments, was during the time covered by this book becoming a respected source of human understanding. This is apparent in the treatises on musical instruments of the time, such as Praetorius's **De Organographia** and Mersenne's **Traite des instruments** (see EMI Vol. V #1), in their greater attention to construction details and acoustical characteristics. In Cohen's terms: "the new science, in contrast (to Aristotelian empirical science), observes, as it were, not 'natural' nature, but an artificial nature, never to be seen in daily life." For example, frequency of string vibration occurs too rapidly to be directly observable, as Galileo noted, but it became possible to construct artificial devices by which vibrational motion could be observed and measured. "Such a process of forcing nature to exhibit phenomena not normally produced is called 'experimenting.'" (Cohen, pp. 8-9).

With the composer Vincenzo Galilei (1520-1591),

"for the first time **the musical instrument was made the subject of theoretical analysis.** Now the musical instrument constitutes a piece of 'artificial nature' **par excellence.** What is valid for the Scientific Revolution as such applies to the new musical science as well: theorists began to make use of the treasures of empirical evidence hidden in the workshops of the instrument makers. This development, which would find a first culmination point in the work of Mersenne, was clearly adumbrated by Vincenzo Galilei. He inferred from elementary musical practice with string instruments that pitch can be varied by changing not only the length or the tension of a string, but also its thickness or the material it is made of" (Cohen, p. 85).

Vincenzo's son, the astronomer and lutenist Galileo (1564-1642), verified these assumptions in experiments with pendulums, músical glasses and sympathetic resonance, but felt that the vibrational motions of musical strings were too rapid to be quantified.

Marin Mersenne (1588-1648) extended and refined Galileo's acoustical experiments:

"In Mersenne's hands a process was completed that had started with father and son Galilei: the musical instrument was turned into a scientific instrument, capable of revealing nature's hidden properties. Not the least important reason why the **Traite des instruments** in **Harmonie universelle** contains such important information is the fact that Mersenne used the instrument makers themselves as a direct source of knowledge ... Of course, the latter could only provide the raw material for theoretical reflection, but the point is that without it, no sensible theory formation was at all possible." (Cohen, pp. 101-102).

The Galileis and Mersenne had vigorously attacked the "mistaken" Pythagorean proposition that the ratios of weights suspended on otherwise identical strings were directly proportional to the strings' frequency ratios. But formulating a precise and correct physical concept of tension and its relation to frequency was difficult. It required a redefinition of the idea of 'weight' in terms of force, mass, motion and time, concepts that were relatively new and not fully articulated in those days. These notions were combined by the astronomer Johannes Kepler (1548-1620) in his laws of planetary motion, which were for him, like Ptolemy, problems of cosmic harmonics. Kepler, in fact, contributed to all three of Boethius's 'kinds of music,' cosmic, human, and instrumental. "The search for the laws of harmony governing the heavens as well other domains of nature was, from beginning to end, Kepler's **central research program** out of which the laws of planetary motion branched amidst many other natural laws" (Cohen, p. 15).

The early acoustical experimenters had no particular reasons to be forgiving of Pythagoras's "error," but they could have been more understanding. Within the framework of Pythagorean assumptions about nature and number, where basically number is nature and the ratios and proportions of numbers were regarded as the essence of the natural relations, there is no "error." Similarly Vincenzo Galileo claimed that the fundamental frequency of sounding pipes was related to the cube of their volume, and Mersenne flatly denied that trumpets produced the 7th harmonic partial. Although both notions are quite "wrong" they nevertheless derive quite consistently from those musician-scientists' own understanding of the nature of sound. **Quantifying Music** contains an extensive analysis of the mistakes and limitations of early acoustical-musical science. The point of analyzing untenable theories is "that the history of science consists of many more wrong than correct theories, and that a historian who is interested only in the latter cannot be said to do justice to its subject matter....wrong theories can teach us considerably more than correct ones about the difficulties inherent in the process of the advancement of learning" (Cohen, p. 150).

FOOTNOTES:

1. The term "rule" (L. regula, Gk. kanon) means variously a calibrated stick or a procedural guide and a standard of judgement, as well as specifically the monochord which embodies and make audible the mathematical principles said to govern reason in musical thought. These meanings of the monochord, as an instrument capable of revealing and demonstrating both mathematical and musical (at least acoustical) phenomena, have endured even to the current designation of the device in international scientific vocabulary as a sonometer.

(continued at right below)

NOTICES

QUARTZ CRYSTAL "SINGING" BOWLS -- perfect musical instrument -- each bowl plays a different musical note -- especially helpful for music therapy -- the bowls make people smile -- they are perfect stress eliminators -- 12 sizes -- frosted & clear -- chakra-tuned -- all credit cards accepted -- The Crystal Store -- 1-800-833-2328.

SOUND SCULPTURE: Recording engineer and producer OLIVER DI CICCO will show his sonic sculpture as part of San Francisco's Open Studio program, on Saturday & Sunday, November 10th & 11th from 12:00 to 5:00 pm. His works will be on display at Mobius Music recording studio, 1583 Sanchez St., San Francisco, CA 94131. For more information call (415) 285-7888.

MICROTONAL MIDI TERMINAL (vers. 1.2) by Denny Genovese lets you play nearly any MIDI synthesizer in Just Intonation! A veritable "tuning processor" as well, it has many features for constructing, editing, transposing, analyzing and printing Just Scales. Tuning data is shown in Ratios, Cents, Frequencies and Yamaha TU's. Those without a MIDI instrument can hear the Just scales on the computer's built in speaker. Holds 16 scales in memory, which are selected by single keystrokes. Tunings may be transposed into any key with another quick stroke. Requires IBM XT/AT or compatible and, for performance, an MPU-401 or compatible MIDI interface. $60 from DENNYS SOUND & LIGHT PO Box 12231 Sarasota, FL 34278.

Richard Kassell writes: I will be giving two talks on my favorite subject (HARRY PARTCH) at the joint annual meeting of the American Musicological Society, Society for Music Theory and the Society for Ethnomusicology (whew!), which takes place this fall at the Oakland, California Convention Center and Hyatt Regency. The talks are: 1) Friday, November 9 at 1:30 pm, the first of three papers in an AMS session, a talk entitled The "Bitter Music" of Harry Partch; and 2) Saturday, November 10 at around 3:30 pm, the third of four papers in an SMT session, a talk entitled Harry Partch's Monophony: A System of Just Intonation. Room locations as yet undetermined; if you are interested, send your local (Bay Area) phone number (along with any brief questions, including a SASE) to Richard Kassell at 245 East 24 Street #3E, New York NY 10010. I'll do my best to let you know the locations when I know.

The duck went to the pharmacy to buy some chapstick. "Cash or charge?" the cashier asked. The duck replied, "Just put it on my bill."

WIND, STRING, PERCUSSION DEMO/TECHNIQUE CASSETTE -- 60 min.. Waterphones on side A, many other instruments & sound devices on side B. Send $8 + $2 (pack. & ship. -- $3 for overseas). $8 is deductable from purchase. Richard Waters, 1462 Darby Rd., Sebastopol, CA 95472, USA.

"PROSE IN CANNES" is a radio show on Macalester College's FM station WMCN. The show will expressly exhibit and entertain experimentation. All contributions of either primary or secondary nature are welcome (cassette, 1/2" or 1/4" loops, etc.). Write in care of: Roger Skulback, 1600 Grand Ave., St. Paul, MN 55105.

Frog Peak Music announces version 4.0 of the HIERARCHICAL MUSIC SPECIFICATION LANGUAGE. HMSL is an interactive programming language for experimental music. It gives the user numerous tools for exploring algorithmic composition and real time interactive performance. Versions available for Macintosh and Amiga. A cassette featuring 12 HMSL composers is available for $8. Further information from Frog Peak Music, PO Box 151051, San Rafael, CA 94915.

GLASS MUSIC ENSEMBLES or anyone having information about current performing glass music groups -- please send information about these, no matter how obscure or based on rumour -- to E. Cadesky, Glass Orchestra, 211 College St. #115, Toronto, Canada M5T 1R1. Most interested in contemporary and ethnic glass music from North American or other cultures.

JUST INTONATION CALCULATOR by Robert Rich. Composer's tool for JI. Internal sound for tuning reference; shows modulations; reduces fractions; converts between ratios, cents, DX7II/TX81Z units; MIDI tuning dumps. Requires Macintosh with Hypercard -- only $10.00. Soundscape Productions, Box 8891, Stanford, CA 94309.

PLANET HARP is a newly released cassette of original harp music for Ngombi, a traditional harp from Gabon, and the Moon Harp, designed by Catherine Favre, inspired by the Finnish Kantele. Available through Studio Luna, PO Box 252, Half Moon Bay, CA 94019. $10 plus $1 shipping; make checks to Catherine Favre.

SOUNDINGS 16: AN ANTHOLOGY. The latest from Soundings Press includes material from several sound artists working with new & unusual sound sources: Sarah Hopkins, John Zorn, Gordan Monahan and several more. 176 pages; $20/copy, from Soundings Press, PO Box 8319, Santa Fe, NM 87504-8319.

DIDJERIDUS -- Play this aboriginal wind instrument yourself. Find out why composers & players of avant garde and experimental music are re-discovering the oldest wind instrument in the world. Instructional cassette included. $85.00. For information call or write Fred Tietjen, 26 Allen, San Francisco, CA 94109; (415) 474-6979.

THE ONLY BOOK IN SAWING: **Scratch My Back: A Pictorial History of the Musical Saw and How to Play It**, by Jim Leonard and Janet Graebner. Features profiles of sawyers world-wide in 124 pages of fascinating information. Includes over 100 photos and illustrations, index and bibliography. U.S. Dollars $19.95, $3 shipping/handling (in CA add 6% tax). For information, contact Janet E. Graebner, Kaleidoscope Press, 1601 West MacArthur, #12F, Santa Ana, CA 92704.

EMI BACK ISSUES: Back issues of **Experimental Musical Instruments** numbered Volume VI #1 and later are individually available for $3.50 apiece. Earlier issues available in volume sets of 6 issues each, photocopied and bound: Volumes I through V, $14 per volume. Order from EMI, PO Box 784, Nicasio, CA 94946, or write for complete listing. Corresponding cassette tapes also available for each volume; see information below.

CASSETTE TAPES FROM EMI: **From the Pages of Experimental Musical Instruments**, Volumes I through V, are available from EMI at $6 per volume for subscribers; $8.50 for non-subscribers (each volume is one cassette). Each tape contains music of instruments that appeared in the newsletter during the corresponding volume year, comprising a full measure of odd, provocative, funny and beautiful music. Order from EMI, Box 784, Nicasio, CA 94946.

A REMINDER -- Unclassified ads here in EMI's notices column are free to subscribers for up to 40 words; 30 cents per word thereafter. For others they are 30 cents per word, 15 word minimum, with a 20% discount on orders of four or more insertions of the same ad.

Book review footnotes, continued

2. Here Boethius is engaged in an intricate play of meanings on the notion of "weight." The Latin momentum (movement, motion) translates Gk. rhope "which denotes a weight used on a scale, but also connotes the critical moment of judgment, the turn of the scale." Pythagoras discovered "his rule, his measure of consonances, in the weight (pondus) of the hammers used in the smithy." He subsequently 'weighs' or 'ponders' (L. perpendo) his theory of consonances." (Bower, Notes 52, 69, pp. 12, 17) In these experiments the suspended weights are the variables on which the ratios of the consonances depend--a momentous observation.

RECENT ARTICLES IN OTHER PERIODICALS

The following is a selected list of articles of potential interest to EMI readers which have appeared recently in other publications.

MAKING THE TRADITIONAL INSTRUMENTS OF CAMBODIA by William Lobban, in Cultural Survival Quarterly 14(3) (11 Divinity Ave., Cambridge, MA 02138).

In addition to providing an overview of traditional Cambodian instruments and their manufacture, this three-page article discusses the challenge of recreating Cambodian fine art music following the cultural decimation of the Pol Pot era.

JOE BARRICK'S ONE MAN BAND by Hal Rammel, in Musical Traditions #8, early 1990 (98 Ashingdon Rd., Rochford, Essex, England SS4 1RE).

This is an extended version of the article on the history of one man bands that appeared in EMI Vol. V #2. Several more early woodcuts and contemporary photographs, as well as some additional text, appear in this version.

PERCUSSION FROM SCRATCH by Mark Dery, in Drums & Drumming, June/July 1990 (GPI, 20085 Stevens Creek Blvd., Cupertino, CA 95014).

This is a report on contemporary homemade instrument builders across the U.S., with information on and quotes from a wide range of people working in the field. Shorter versions of much the same article appeared in The New York Times Sunday Arts & Liesure section of August 19, and The Chicago Tribune "Tempo" section April 3rd. Thanks to author Mark Dery for steering this information on unconventional instrument makers into the mainstream press.

TECHNICAL DULCIMER by Sam Rizzetta, in Dulcimer Player News, Vol. 16 #3, July-Sept. 1990 (PO Box 2164, Winchester, VA, 22601).

The author discusses means for reducing sustain time on hammered dulcimers, including pedal-operated dampers, permanent dampers and mutes added to the bridge, and aspects of playing technique and hammer selection.

Also in this issue of Dulcimer Player News, in the "News & Notes" section, is a brief report on the appearance of Dick Bell at the Great Black Swamp Dulcimer Festival. Dick Bell took first prize at the 10th annual Strange Music Festival in Kentucky earlier this year, playing bugle calls on a swung trumpet he calls the Hosaphone.

SFERICS: A BEGINNER'S GUIDE TO WHISTLERS, TWEEKS, AND OTHER NATURAL RADIO SOUNDS AND HOW TO HEAR THEM by Mike Mideke, in Whole Earth Review #68, Fall 1990 (27 Gate 5 Rd., Sausalito, CA 94965).

A practical guide to making radio receivers (some extremely simple and inexpensive) to pick up natural electromagnetic signals. The article also discusses the sources of the most common radio signals. Several more articles in the same issue explore related possibilities.

MAKING A HARP SOUNDBOARD by Hilliard Stone, in Folk Harp Journal #69, Summer 1990 (4718 Maychelle Dr., Anaheim CA 92807-3040).

A straightforward description of harp soundboard construction, with diagrams.

MICHEL DENEUVE ANOTHER GEM IN THE FESTIVAL CROWN, in Glass Music World Volume 4 #3, July 1990 (2503 Logan Dr., Loveland CO 80538).

Brief notes on Michel Deneuve and one of his recent performances. Deneuve is the leading performer these days on the Baschet Brothers' glass and steel rod instrument called Cristal.

A NEW MANDOLIN FAMILY by Otis A. Tomas, in American Lutherie #22, Summer 1990 (8222 S Park Ave, Tacoma, WA 98408).

The author describes his work in developing a family of four mandolins scaled proportionally to their pitch ranges.

Also in American Lutherie #22: another in Robert Lundberg's fine series on historic lute construction, an interview with the maker of the very successful Peavey guitars & amps, and more.

The Gourd Volume 20 #2, Summer 1990 (PO Box 274, Mt. Gilead, OH 43338) has several articles on gourd instruments:

THE OXFORD GOURD ENSEMBLE by Larry Sherman discusses Sherman's conceptual artwork of the same name, which he likens to a running gourd vine: the ensemble exists as the ongoing, ever growing and changing connection between the ensemble's director (Sherman), and all those who over the years have come in contact with or played music with him and his gourd instruments. This work was also described in EMI Vol. II #6.

THE NATURAL HORNS by Bart Hopkin is a brief description of some of the possibilities for trumpet-like instruments of gourd.

A TRUE AGS GOURD MUSICIAN describes the work of Bill Jenkins, owner and player of a large collection gourd instruments from around the world, which he uses in concerts and classroom presentations.

MIRACLE ROOM by Darren Ressler, in Option #34, Sep/Oct 1990 (2345 Westwood Blvd. #2, Los Angeles, CA 90064).

A report on the band Miracle Room, which uses basic rock instrumetation augmented by found sounding objects and simple junk instruments.

HARRY PARTCH / EXPERIMENTAL COMPOSER by Moniek Darge, in Logosblad July 1990 (Kongostraat 35, 9000 Gent, Belgium).

Most articles appearing in the Logos Foundation's newsletter, including this one, are in Dutch. Articles in English and other languages do occasionally appear as well.

TEACH IN: MAKING A BASSCAN by Joe Broadman in Sing Out! Vol. 35 #2 (125 E. 3rd St., Bethlehem, PA 18015-5253).

This article provides plans for the construction of a basscan -- a single-string upright bass using a large empty potato chip can as resonator.

WASHBOARD SLIM 1900-1990 by Saul Broudy, also in Sing Out! Vol. 35 #2 (address above).

This is an obituary for Robert Young, the percussionist who played a washboard hung with an array of other metal sound sources in and around Philadelphia from the 1940s until his death.